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THE COMBINED EVALUATION OF EFFICIENCY AND BIOMOTOR PARAMETERS, USING UNCONVENTIONAL DEVICES TO MONITOR THE EVOLUTION OF HANDBALL PLAYERS IN COMPETITIONS

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List of abbreviations

2’ O.= 2-minute obtained suspension
2’= 2-minute suspension
7M O.= 7 meter obtained
7M P.= provoked 7 meter
7M+2’= provoked 7 meter and 2-minute suspension
A.7m = 7-meter shot
A.C. = shots on the fast break
A.C.A. = in contact shot after assist
A.D. = shots after overtake
A.F2 = second phase shot
A.Î.9m = 9-meter crossing shot
A.L.A. = free shot after assist
A.P. = standing shot
A.P.D. = position shot after overtake
A.P.G. = empty net shot
A.P.S. = 6-meter line breakthrough shot
A.P6m = 6-meter breakthrough shots
A.S.9m = 9-meter jump shot
A.T. = total shots
AL= lactic acid
AMMD= medicine-ball right side throw
AMMS= medicine-ball left side throw
AP = average power
AV = average velocity
B.A.= shot blocking
C = center back
C.Ap.S.J.= the coefficient of standardized positive actions in the game
C.E.T.J.= overall efficiency coefficient in the game
C.G.E.= global efficiency coefficient
C.G.J.= game error coefficient
C.G.S.J.= the standardized error coefficient in the game
C.R.= red card
C.S.= strain coefficient
C.U.= utility coefficient
CE= European Championship
cm = centimeters
CM= World Championship
CMJ AF= countermovement jump, arms fixed
CMJ AS= countermovement jump, arms swing
Cv = variability coefficient
D.= steal
D.D.= double dribble
Dif.X = difference between averages
ED = right wing
ES = left wing
F.A.= offensive foul
F.C.= lane formation
F.T.= technical foul
FC = heart rate
FC_{max} = maximum heart rate
G.7m = 7 m penalty goals
G.C. = goals scored on the fast break
G.D. = goals scored after overtake
G.P. = goals scored from the wing position

G.P6m = goals scored in 6m breakthrough
G.S9m = long range goals scored from the backcourt position
G.T.= total goals scored
G= serum glucose
GCT = ground contact time
I.= interception
Î.C.= lane close off
ID = right back
IS = left back
JH = jump height
JO = Olympic Games
kg = kilograms
km/h = kilometers per hour
L.M.= no marking/ absence of marking
m = meters
M.N.= ball not intercepted/failure to regain the ball
M.R.t.= ball intercepted/regained on the court
M.S.= dropped ball
m/s = meters per second
max. = maximum
Min = minimum
min. = minutes
N.C.= lack of lane close off
P = pivot
P. Comp. = competitive season
P.= steps
P.D.= assist
P.G.= missed pass
P.R.= successful defensive wall;
P.Tr. = transition period
Pc. = foot
PP = peak power
PV = peak velocity
R.E.= efficient turnover
R.M.= regaining ball possession after goal save
RSI 1 = reactive strength index
RSI 10/5= countermovement jump RSI 10/5 (reactive strength index)
s = seconds
S.= 6-meter line
S.G.=wrong switch
SD = standard deviation
SJ = squat jump
T1 PA = after warm-up test in active recovery conditions
T1 PP = after warm-up test in passive recovery conditions
T2 PA = final test in active recovery conditions
T2 PP = final test in passive recovery conditions
TA 10m= 10-meter acceleration test
T_c= body temperature
T_m= muscle temperature
V_{IFT} = peak velocity reached in the 30-15 IFT Test (velocity intermittent fitness test)
VO_{2max}= maximum oxygen uptake
w = watts
X = arithmetic average

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INTRODUCTION

Modern handball is one of the fastest team sport games, characterized by repeated jumps, sprints, changes of direction, physical contacts at high speeds and specific technical actions in response to various tactical situations during the game (Karcher & Buchheit, 2014) and its quality is influenced by factors such as individual efficiency (physical, physiological, technical), collective efficiency (tactical strategy, social factors) or external factors (environmental and material conditions).

The strategy of the match, the evolution of the game, the mentality or preferences of the coaches, the possible injuries or the low performance of the teammates are the situations that require the exchange or rotation of the players (the on court ones with the substitutes). Moreover, the numerous physical contacts and the fast playing pace in modern handball, raise the need to exploit the potential of all players in the team, in order to preserve the optimal performance capacity and delay the onset of fatigue. In this situation, any player who enters the match must respond with maximum efficiency to immediate demands (physical, functional and technical-tactical) on the court, so as to maintain a high playing level and not negatively influence the evolution of the team until that moment.

The aspect that caught our attention is the period of passive recovery (PP) or inactivity that follows the warm-up for the match and which applies to substitute athletes. Although re-warming up, which we call active recovery (PA), is allowed, it must occur behind the benches, without the ball, and only if the available space allows it.

MOTIVATION FOR THE CHOSEN TOPIC

As a former performance athlete, I can say that my own experience as a player, dealing with performance fluctuations, numerous injuries or sacrifices, working with different coaches throughout my career, who had various training methods and game strategies, represent the struggle and at the same time my inner motivation that challenged me to approach this topic.

In choosing the research topic, I started from a simple observation of the latest trends in the game of modern women's handball. What particularly drew my attention was harnessing the potential of all the players, by their efficient exchange during the matches and the distribution of an approximately equal playing time, during the European Championship in 2018. The team that used all its players the most was that of France, which also won the first European title in the country's history, after becoming the world champion for the second time a year before[1]. Three years afterwards, in a recent interview with the French coach, Olivier Krumbholz, he drew attention to the danger of using the same players during matches. If we analyze the situation of the national senior team of Romania, we can see that our country has a long tradition in playing handball, but lacks the superior achievements obtained in major international competitions. According to the data, the women's national team is the only one in the world that has managed to qualify for all editions of the World and European Handball Championships. However, in 2021, there are very few trophies in the team's record (only 5).

The professional experience gained over the years, in different teams in the National Handball League and in Romania's representative team, at all age levels, allows me to emphasize the importance of optimal training for effort to ensure a good efficiency in the game of women's handball, which most times has a decisive impact on the final result of any competition.

At present, we have been able to discover **very few works that address the strategy of rotating players during handball competitions**. Moreover, **the study of the effects of the passive recovery and the appropriateness of implementing the active recovery are topics debated mainly in other games or sports and are the subject of research abroad, not in our country**. In addition, **the identified sources in handball are made in regards to the male players**, which may not be too relevant for girls, due to different physical, physiological, technical-tactical and psychological peculiarities.

[1] "France women's national handball team". Available at: https://en.wikipedia.org/wiki/France_women%27s_national_handball_team [accessed on 13 July 2021].

By investigating the factors that influence the ability to achieve performance, we wish to be able to make a modest contribution to identifying and eliminating any obstacles that may affect the optimal performance, during competitions, of female handball players. Thus, proposing a well-documented method of exploiting the full potential of the entire team can provide real support to both coaches and especially players, in order to improve individual and collective efficiency in the game.

CURRENT LITERATURE

In Romania, the scientific interest associated with identifying strategies to maintain the benefits of warming up in order to optimize performance in the game of handball in general and in relation to substitute players in particular, is limited. Moreover, the analysis of the evolution of players during matches or training is an under-utilized area in our country, although worldwide it is on the list of sports performance success factors. However, general information about sports measurement and evaluation has been published by authors such as Virgil, T. (2005) or Rîșneac, B. (2004).

Because we wanted to carry out the combined evaluation of handball players, the approach of our bibliographic research was directed towards three main directions: physical, physiological and efficiency responses in the game, as a result of following the two recovery protocols (passive and active). We also paid special attention to modern technological devices, used in current sports training and competitions.

Initially, we identified many studies, from various games and sports, including cycling, mountaineering or canoeing (Bogdanis et al., 1996; Connolly et al., 2003; Draper et al., 2006; Mika et al., 2016). However, taking into account the particularities of the handball game compared to other team sport games, we were guided by the reference study of Bompa (2002), who made a classification of sports according to effort characteristics and training requirements. Thus, we noticed that the biological systems and spheres of stress/exertion in the game of handball are similar to those in the game of basketball, football and volleyball or sports events such as athletics and they concern neuropsychological, endocrine-metabolic and neuromuscular aspects.

International scientific research is of particular interest in the monitoring, analysis and evaluation of physical, physiological and technical-tactical abilities in the game of handball, at all age levels, both male and female. Particular attention is paid to the differences in particularities between positions (Cardinale et al., 2017; Havolli et al., 2020; Hermassi et al., 2019; Karcher & Buchheit, 2014; Karpan et al., 2015b; Manchado et al., 2020; Mohoric et al., 2021; Weber et al., 2018) and today, through modern technology, researchers can provide accurate information about the current demands of the modern handball game, specific to each position (Manchado et al., 2020).

The analysis of the fatigue phenomenon is also of major and continuous interest among specialists. Overexertion of athletes causes a decrease in the physiological, physical and efficiency responses of players. The main reason was determined to be the accumulation of a very long playing time, which led to a decrease in performance, especially in the second half of the match (Chelly et al., 2011; Michalsik, Madsen, et al., 2013; Ortega-Becerra et al., 2020b; Póvoas et al., 2012, 2014b; Wagner et al., 2014; Wik et al., 2017). For example, two studies have identified the presence of fatigue in the second half of matches, reporting, in girls, a decrease of 21.9% in the case of high-intensity running (Michalsik, Madsen, et al., 2013), while the boys recorded a decrease of 16.2% (Michalsik, Aagaard, et al., 2013). Another possible reason for the decrease in performance in the second half, in various team sports, was suggested to be inactivity during the intermission between the halves of the match (Hammami et al., 2018; Russell et al., 2015; L. M. Silva et al., 2018). The analysis of the 2016 edition of the Rio Olympic Games indicates that 19% of all injuries were caused by overstressing the athletes (Soligard et al., 2017). In handball, a recent study conducted during a men's competitive season indicates that there is an incidence of 6.0 injuries per 1000 hours of training and matches (Hammami et al., 2018).

Being a standard procedure performed before any sporting competition, the role of warming up has been intensely studied since the 1930s (Galazoulas, 2012). As a result, the literature provides a wealth of information on the importance of warm-up in optimizing performance in various sports competitions (Anderson et al., 2014; Bishop, 2003a, 2003b; Chen et al., 2021; McGowan et al., 2015; McMillian et al., 2006; L. Silva et al., 2018; Turki et al., 2012; Zmijewski et al., 2020; Zois et al., 2015) and in the prevention of possible injuries (McCrary et al., 2015; Woods et al., 2007).

Although it has been suggested that a player rotation can be an effective strategy for maintaining optimal effort capacity during matches, it is rarely used and studies on this topic are limited. The first and only study of handball on the impact of exchanges between players investigated the effects of distributing shorter periods of play compared to longer ones (Moss & Twist, 2015). Players achieved better physical results in short intervals due to lower physiological demands and the researchers concluded that a good distribution between playing and recovery periods could reduce the physical and physiological overloads that cause fatigue and thus decrease the efficiency of players. Therefore, we can say that ***a good preparation of the body for effort becomes crucial***.

Recent studies provide significant recommendations on the most effective warm-up protocols for competition in various team sport games and provide reactivation strategies for players in two situations: ***in the time interval between the end of the warm-up for the match and the start of the matches*** and ***during the break between halves*** (Hammami et al., 2018; Russell et al., 2015; L. Silva et al., 2018).

However, none of the evaluated studies also refers to any strategies applied to handball players who remain inactive immediately after the start of the match, although they can be substituted at any time, according to the rules of the game and should perform at maximum capacity from the first moment of the match.

From our current information, the period following the initial warm-up, in the form of a passive or active recovery, is insufficiently examined in the game of handball. The literature presents the effects of passive recovery (PP) during physical activity as often negative on the subsequent, immediate evolution of athletes. Its greatest benefits come only after the cessation of physical exertion. Although it is very useful in restoring the biological potential that is sometimes endangered by exhaustion (Demeter, 1976) PP in a standing or sitting position can lead to a decrease in muscle tone (Șerban, 1983). This situation can negatively affect the eventual evolution of athletes during basketball competitions (Crowther et al., 2017; Galazoulas, 2012) and may increase the incidence of handball injuries, which has already been reported to be very high (Wedderkopp et al., 1999; Mónaco et al., 2019).

The only handball study we were able to identify detected the effects of passive and active recovery on the process of eliminating lactic acid from the blood, in the case of a men's team (Arazi et al., 2012). As the differences in gender peculiarities have been well highlighted over time (Michalsik, Madsen, et al., 2013, 2015; Michalsik, 2018b; Mónaco et al., 2019; Póvoas et al., 2014b; Wagner et al., 2020; Weber et al., 2018), the results of this study are of limited relevance to women's handball.

Concerns about substitute players, their inactivity, and the effects of active recovery in the substitution area are prevalent in football or hockey games (Arslan et al., 2017; Kilduff et al., 2013; Lau et al., 2001; Spierer, 2004), or individual sports such as gymnastics, swimming, athletics or climbing (Buchheit, Cormie, et al., 2009; Draper et al., 2006; Dupont et al., 2003; Jemni et al., 2003; Signorile et al., 1993; Toubekis et al., 2008). But all this research has yielded conflicting results. PA has been shown to be beneficial in some research, contrary to other analyses that have shown that PA has negative effects on subsequent sports activities and should not be used.

Existing studies generally include the analysis of physical and physiological demands but do not refer to the effectiveness of the technical actions of the players. We believe that since many technical actions occur with physical contact, this omission may lead to an underestimation of the evaluation of athletes, in the modern game of handball.

This research has an innovative character in that it aligns with the technological progress registered in the sports field, at the level of all disciplines. In our bibliographic approach, we have identified examples for the use of new technological tools in almost all recent articles, which have guided us in choosing the research methodology. **External stresses** can be measured using global (GPS) and local (LPS) positioning systems, inertial measurement units (IMUs), or video monitoring systems (Buchheit & Simpson, 2017; Hoppe et al., 2018; Luteberget et al., 2017; MacDonald et al., 2016; Maric et al., n.d.; Orange et al., 2019; Prieto-Lage et al., 2018). **Internal stresses** can be tracked through many portable applications and tools that provide information on the most important functional parameters such as heart rate (Bělka et al., 2014; Buchheit, Lepretre, et al., 2009; Navalta et al., 2020), lactic acid (Arazi et al., 2012; Ortega-Becerra et al., 2020b; Özsu et al., 2018), skin or muscle temperature (Crowther et al., 2017; Galazoulas, 2012; Hills et al., 2020; Mohr et al., 2004; Tong et al., 2019; West et al., 2016).

At the end of our bibliographic exploration, we found that, in addition to the studies conducted in the game of basketball, most research has implemented the two recovery programs (passive and active), as methods of recovery ***after exertion*** or as reactivation of the body ***during breaks***, ***between the halves*** and *not after the initial warm-up*, on the edge of the court where the official competition takes place.

IMPORTANCE AND AIM OF THE STUDY

The importance of the thesis is given by the high degree of topicality in the research, which has been thoroughly documented and verified by a large-scale scientific approach. The material will be of use to coaches and specialists in the field because it offers an innovative way to harness the potential of the entire team of players. In this regard, we will provide *an innovative and accessible method of optimizing the effort capacity of substitute players*, according to the requirements of the modern handball game, regardless of when they are introduced on the court. Moreover, we will develop *a formula for quantifying the efficiency in the game*, according to each position, which will provide coaches with one of the most objective methods of evaluating players.

In order to perform the game tasks, athletes must have an optimal preparation of the body for effort, which ensures the functioning at optimal capacity of the main biological systems required by the game of handball (cardiovascular system, respiratory system, neuromuscular system, musculoskeletal system). *In our opinion, regardless of the value of the players in positions, given that their substitution occurs with insufficient training, due to the period of inactivity on the side line, their immediate performance can affect the collective game by poor efficiency and can even lead to injuries.*

We believe that *by replacing the passive recovery and implementing an active recovery protocol, we will contribute, on the one hand, to optimize the start shape of the substitute players and, on the other hand, to increase their efficiency in the game*. Pairing this innovative strategy with the current need for player rotation in order to maintain a high level of in-game performance and reduce fatigue (Karcher & Buchheit, 2014; Michalsik, 2018b), we believe that our work can be a relevant answer to the attempts of specialists to find the safest ways to achieve their goals and achieve the best sports performance.

The importance of our work is also established by *the research methodology which is composed of innovative tests and unconventional tools for monitoring the physical and physiological capacity for effort*.

Establishing the performance model in the game of handball is the research interest in many recent scientific papers and *we believe that this minor aspect addressed in our thesis, but which may have a major impact on the final results of competitions, finds its place on the list of the most important factors influencing sports performance*.

The aim of this paper is *to investigate and compare the effects of two recovery programs (passive and active), implemented immediately after the match warm-up, on the physical, physiological and efficiency responses in the game, in the case a women's handball team in Romania, by using unconventional monitoring means*. In this sense, we will develop a *combined assessment* matrix, at different times and under different conditions, both in training, and in training or friendly matches. As the substitution area on the side of the handball court is small, we will aim to develop a protocol to maintain the body's readiness for effort, through efficient means that do not require very large areas of implementation.

PART I: THE THEORETICAL AND SCIENTIFIC FRAMEWORK OF THE THESIS

CHAPTER 1. SPORT PERFORMANCE AND PERFORMANCE CAPACITY

1.1. Performance factors in the game of handball

Aerobic and anaerobic capacity, the ability to make successive changes of direction, accelerations and decelerations or high-intensity actions, coordination, strength, flexibility, the ability to sprint or jump, are the requirements for the best results (Karcher & Buchheit, 2014; Manchado et al., 2013; Michalsik, 2018b; Michalsik, Madsen, et al., 2013; Moss et al., 2015; Póvoas et al., 2012).

Being a team sport game, handball is strongly influenced both by the technical-tactical aspects of the attack and defense phases, as well as by the social or mental factors inside or outside the team (Michalsik, 2018b). The model presented in Figure 1. 1 is based on the most relevant studies in the field and explicitly states the complex conditions required by the modern game of handball, both individually and collectively.

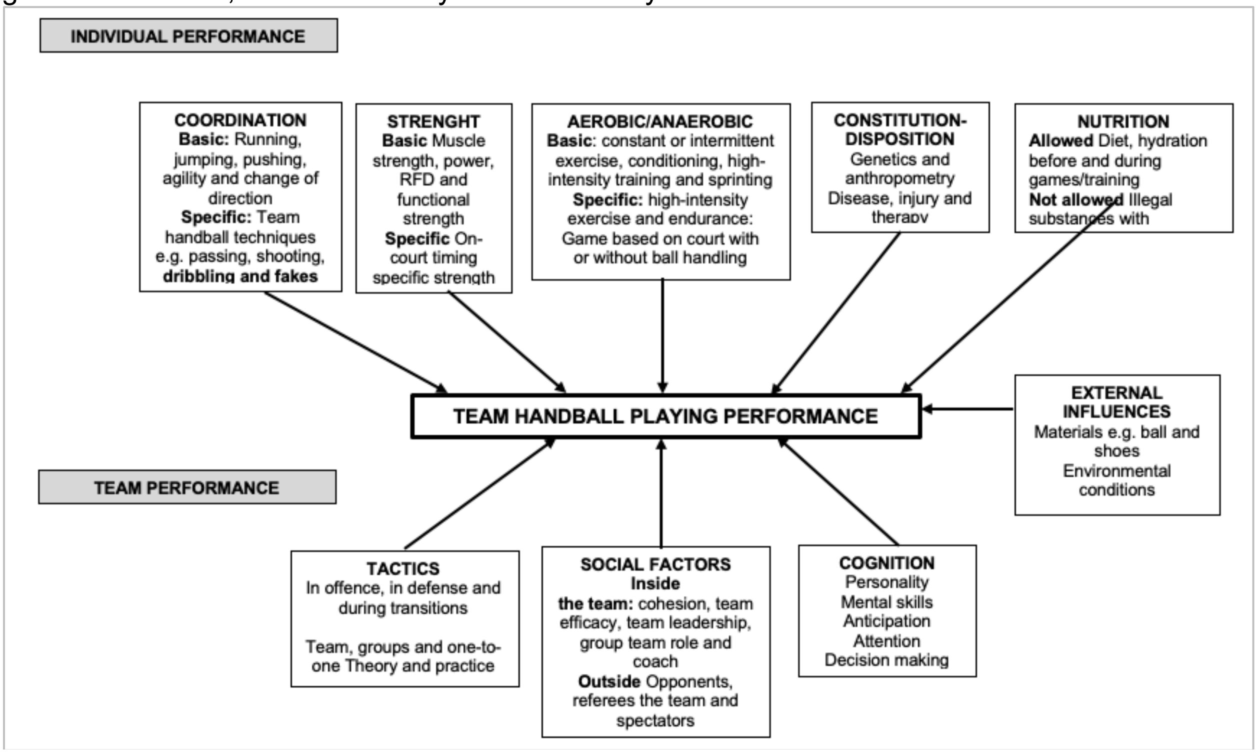


Figure 1. 1. Individual and collective factors influencing the performance in the game, according to Michalsik (2018)

1.2. Performance indicators in the game of handball

A recent study has made a hierarchy of success indicators at the 2017 World Handball Championship, both for women and men (Noustos, 2018). Researchers have identified the same performance indicators, but with a different weight of influence. Thus, for men, what mattered most was the level of professional experience and then shot efficiency and the anthropometric indices, while for women, the combination between the level of experience and shot efficiency was decisive, the anthropometric factor being less important.

Our own research, conducted following the 2019 World Women's Handball Championships in Kumamoto, confirms the results of Noustos (2018), the experience and efficiency of the players being the main performance indicators in this competition. In Table 1. 1, we detailed the average values of the differences registered between the Romanian team (12th place) and the teams on the competition podium, in the case of the performance indicators followed.

Table 1. 1. The performance indicators registered by the Romanian team, compared to the winning teams from C.M. 2019, according to us [2]

Indicators/Team	Netherlands (1st place)	Spain (2nd place)	Russia (3rd place)	Romania (12th place)
International experience (%)*	90.9	71.6	70.6	36.7
Goal efficiency (%)	60	62	68	52
Shot efficiency (%)	53	52	57	42
Age (years)	25	28.3	27.5	25.8
Height (cm)	176	173	178	178
Weight (kg)	71	68	70	70

* the percentage of players with international experience in each team

[2] Gheorghe, C., Mereuță, C. (2020). An analysis of the Collective effectiveness of the Romanian National Team's Attacks During 2019 Women's Handball World Championship, Bulletin of the Transilvania University of Braşov, Series IX: Sciences of Human KinetiC.S. • Vol. 13(62) No. 1 – 2020, pp.17-24, ISSN 2344-2026 (print), ISSN-L 2344-2026 (online), https://doi.org/10.31926/but.shk.2020.13.62.1.2

CHAPTER 2. EFFORT CAPACITY IN PERFORMANCE SPORT

2.1. Effort in the game of handball

The dynamics of effort intensity in the game of handball change mainly in relation to the characteristics of the sport and the sports competition and the level of training and performance of the athletes. Handball players can be continuously active, for 60 minutes, the official period of a match, to which is added the pre-match warm-up part (30-40 minutes). Specialists in sports medicine consider that in the game of handball, the effort analyzed from the energy point of view is a mixed one and it has an anaerobic rate of over 60% compared to the total playing time, the remaining 40% going in the direction of aerobic capacity (Georgescu, 2002, p. 662). Mixed effort is characterized by the release of energy on both biochemical pathways (aerobic and anaerobic) of muscle contraction.

During a handball game, regardless of the level or the opponent, the musculoskeletal system is responsible for performing all specific motor actions (technical actions) and basic actions (running, jumping, walking, etc.), while the neuromuscular, cardiorespiratory systems, ligaments and tendons are subject to variable stresses, ranging from low-intensity actions to maximum or supramaximal intensity, in very short intervals and under changing conditions. Adversity, spectators and the numerous physical contacts between players, with the surface of the court (landings, dives) or with the ball, can also change the intensity of the effort. Other factors that influence the specificity of the handball effort are gender characteristics (female, male) or the position held in the team (during the attack or defense phase).

From the point of view of the required biological systems, Bompa (2002) observed the great amount of activity in the neuromuscular, neuropsychological and endocrine-metabolic systems. The classification of sports made by the author, according to this criterion, allowed us to find that the game of handball has similar features to other team sports such as basketball, football or volleyball or athletics throwing events (Table 2. 1).

Table 2. 1. Biological parameters required by different sports, according to Bompa (2002)[3]

SPORT	PARAMETERS
ATHLETICS	
Sprint	Neuromuscular, endocrine-metabolic, neuropsychological
Middle-distance	Cardiorespiratory, neuropsychological, neuromuscular
Long-distance	Endocrine-metabolic, cardiorespiratory, neuropsychological
Jumps	Neuromuscular, neuropsychological
Throwing	**Neuropsychological, endocrine-metabolic, neuromuscular**
BASKET-BALL	**Neuropsychological, endocrine-metabolic, neuromuscular**
CANOE	Cardiorespiratory, endocrine-metabolic, neuromuscular
FENCING	Neuropsychological, neuromuscular, endocrine-metabolic, cardiorespiratory
GYMNASTICS	Neuropsychological, neurometabolic, neuromuscular
HANDBALL	**Neuropsychological, endocrine-metabolic, neuromuscular**
ROWING	Endocrine-metabolic, cardio-respiratory, neuromuscular
RUGBY	Neuropsychological, neuromuscular, cardiorespiratory
FOOTBALL	**Neuropsychological, endocrine-metabolic, neuromuscular**
SWIMMING	Cardiorespiratory, endocrine-metabolic, neuropsychological
TABLE TENNIS	Neuropsychological, neuromuscular
VOLLEY-BALL	**Neuropsychological, endocrine-metabolic, neuromuscular**

[3] Bompa, T. O. (2001). Periodizarea: teoria şi metodologia antrenamentului. Ediţia a IV-a. Constanţa: Editura Ex Ponto, p. 94.

CHAPTER 3. MEASUREMENT AND EVALUATION IN PERFORMANCE HANDBALL

3.1. The objectives of measurement and evaluation

Recent studies suggest that there is *currently a particular concern for the scientific approach to the process of sports monitoring (Halson, 2014),* one of the main purposes of the evaluation is to highlight the functional changes in the body of athletes, determined by the influences of training or competition (Hermassi et al., 2019; Scanlan et al., 2014; Weber et al., 2018).

Dragnea, A. (1996), quoted and supplemented by Tudor, V. (2005)[4], argues that the *evaluation* activity has the following general objectives:

- knowing the reaction of the athlete's body to the training efforts and the particularities of the development of fatigue and recovery processes;
- determining the level of functional capacities for different systems, organs or functional mechanisms (aerobic, anaerobic, etc.), which have a decisive role in the efficiency of the competitive activity;
- checking the effort indicators (volume, intensity, complexity, breaks, etc.);
- estimating the capacity of effort adaptation;
- testing the level of development for motor skills, technical-tactical and mental training;
- scientifically determining the periods and ways of achieving athletic shape;
- knowing the mental capacity of the athlete;
- comparing the results of competitions with the previously established performance objectives;
- determining the degree of technical mastery and tactical ability;
- highlighting the efficiency of the competitive activity;
- using the results obtained through the evaluation process to scientifically guide the sports training.

Another advantage of combined assessment is the ability to identify the athletes' degree of fatigue. The same volume and/or intensity of effort (distances, playing time, number of repetitions, power of a jump) may generate different responses of the internal physiological indices (heart rate, blood pressure, lactic acid, effort perception), depending on the state of fatigue (Belka et al., 2016; Font et al., 2020; Halson, 2014; Moss & Twist, 2015; Póvoas et al., 2014b; Reche-Soto et al., 2019).

Based on the information presented, we can state that both the knowledge of the external stresses that allow to determine the motor possibilities of an athlete and the internal stresses (physiological and psychological) play an essential role in assessing the effects of training and in determining subsequent adaptations.

3.2. Objective indices and methods for biomotor and technical measurement and evaluation, in handball

Investigations at the place of training or competition consist in recording the physical, functional, biochemical or technical-tactical indicators, in basal conditions, during effort or after effort, with the help of which we can assess the state of health, level of physical development, functional state, effort capacity and efficiency of athletes.

In order to be able to classify the diversity of an athlete's demands, in terms of **effort**, Alexe, N. (1993) makes a clear distinction between the **intensity of the stress** on the body and the **intensity of the effort** (power). The author claims that the stresses on the body express the price paid inside by the athlete (physiological and psychological) in his/her adaptation to the demands imposed by the effort. Their quantification is done by monitoring functional indices such as *maximum oxygen uptake (VO_{2max}), heart rate (F.C.), blood pressure (TA), respiratory rate (FR), temperature (T), lactic acid (AL), glucose (G), exhaustion level perception questionnaires, etc*. These are known in the modern literature as **internal stresses**. Alternatively, the mechanical work done by athletes (**external stresses**) is measured independently of the internal characteristics, by means of *power units (watts, kilograms/time), by speed and space indices, working tempo, number of executions., etc.*

[4] Tudor, V. (2005). Măsurare și evaluare în cultură fizică și sport. Buzău: Editura Alpha MDN, p. 29.

3.3. Methods and means of measuring and evaluating biomotor parameters in performance handball

In Romania, there is currently no official testing protocol, mandatory for participation in the National League, but there are certain control tests proposed by the Romanian Handball Federation, which, however, no longer comply with current physical and effort requirements imposed by game. Many teams still use the 30 m sprint trials, 30 m dribble running, zigzag run around cones, 10x30 m continuous run, double-leg long jump, long-distance handball throwing or triangular movement.

To *determine effort capacity*, some teams use the Cooper test to assess cyclic effort, although the intermittent nature of handball-specific effort involves a combination of cyclic and acyclic movements, which in turn alternate with longer or shorter periods of recovery time. We have noticed that there are recent studies that use and recommend as research methodologies the tests that best simulate the discontinuous effort, with intermittent intensities specific to the game of handball. Among them, the YO-YO, Beep or 30-15 IFT tests proved to be valid and accessible (Buchheit, 2008; Buchheit, Al Haddad, et al., 2009; Čović et al., 2016; Papanikolaou et al., 2019; Valladares-Rodríguez et al., 2017).

If we consider *the evaluation of the maximum anaerobic power* at the level of the lower limbs, the most often used test is still *the standing long jump*. But there are also alternatives such as *vertical jumps, squat jumps or countermovement jumps* used successfully in team sports such as football, basketball, volleyball or baseball, which can provide important information about the ability of athletes to produce the necessary explosive strength in the various technical elements and procedures during matches. At the level of the upper limbs, the maximum anaerobic power can be determined by the medicine ball overhead or side throwing test.

The *equipment* used to assess physical performance is very diverse. The researchers classified the instruments according to the accuracy of the data provided, thus emerging the concept of "gold standards" in measurement and evaluation. Because, however, many specialists in the field do not have access to these means of research, especially for financial reasons, there have been a multitude of commercial devices or applications, which are affordable, useable and can be worn on the body. The most commonly used *portable electromechanical micro devices* are based on the wireless data transmission system and/or the inertial navigation system (SNI). Due to their portability and accessibility, **micro-devices allow the scientific evaluation of physical, technical, tactical or physiological performance under competition similar conditions and sometimes even during competitions (Barrett et al., 2016; T. O. Borges et al., 2017; Lima et al., 2019; Reche-Soto et al., 2019).** The collection and rapid analysis of the transmitted data are actions that help specialists in the field to create a holistic representation of athletes through match analysis (Windt et al., 2020) and to determine more precisely the factors that influence sports performance.

Due to the technological advancement, which has provided modern measuring instruments, the current exploratory methodology approaches the functional state of the body much more effectively. In this sense, by investigating the functional indices, information can be obtained about the biological systems required by each sport (cardiovascular, respiratory, neuromuscular, metabolic, neuropsychic, etc.), thus helping to complete the physiological picture of the effort with accurate and relevant data.

3.4. Methods and means for the technical-tactical measurement and evaluation of players during handball matches

Technical-tactical developments are generally quantified by **match analysis**, which consists of making an inventory of the quantitative and qualitative indicators by classical (manually completed charts) or modern (processing video recordings using software) recording means. Performance indicators tracked by specialists are a selection or combination of variables that quantify the evolution of athletes and have a positive influence on the final results. They can be classified into: match indicators, tactical indicators, technical indicators and biomechanical indicators (Hughes & Bartlett, 2002).

Video analysis is one of the most popular methods of monitoring technical, tactical and physical developments during handball matches, used in studies of the last 15 years, regardless of level or age (Belka et al., 2016; Bilge, 2012; Karcher & Buchheit, 2014; Karpan et al., 2015b; Manchado et al., 2020; Michalsik, Aagaard, et al., 2013; Michalsik, Madsen, et al., 2013; Milanović et al., 2018; Moncef et al., 2011; Ortega-Becerra et al., 2020a; Prieto et al., 2015b; Weber et al., 2018).

3.4.1. Technology in handball

Numerous studies of performance handball have resorted to technology, mainly due to the ease with which fast and relevant data about athletes can be obtained today. Depending on the objectives pursued, we would like to highlight some relevant studies in the field that have used modern research methodologies:

- the assessment of athletes' physical development and training (Borges et al., 2018; Ferragut et al., 2018; Póvoas et al., 2012);
- the analysis of physical and/or physiological performance in various sports competitions (Benson et al., 2020; Buchheit & Simpson, 2017; Fransson et al., 2018; Galazoulas, 2012; Giblin et al., 2016; Haugen et al., 2017; Karpan et al., 2015b; Luteberget et al., 2017; Michalsik, Madsen, et al., 2013; Prieto-Lage et al., 2018; Toubekis et al., 2008);
- the assessment of the research subjects' physical capacity (Wagner et al., 2016; Weber et al., 2018)
- highlighting the influencing factors of sports performance (Bilge, 2012; Chelly et al., 2011; Foretić et al., 2013; Hughes & Bartlett, 2002; Manchado et al., 2013; Milanović et al., 2018);
- the monitoring and analysis of the individual or collective technical-tactical efficiency (Bilge, 2012; Chelly et al., 2011; Foretić et al., 2013; Manchado et al., 2020; Michalsik, Madsen, et al., 2013; Pic, 2018).

CHAPTER 4. CURRENT DEMANDS IMPOSED BY THE GAME OF HANDBALL

4.1. Performance models in women's handball

After reading the literature, we noticed that most of the research is focused on men's handball. The obtained results cannot be transferred to the case of women due to different anthropometric, physical, physiological, technical-tactical and psychological peculiarities. Many of these differences are confirmed by a comparative study of women's handball (Michalsik, Madsen, et al., 2013) and men's handball (Michalsik, Aagaard, et al., 2013) conducted during 5 competitive seasons, the data being collected in parallel from the same subjects (Table 4. 1).

Table 4. 1. The differences between men and women, recorded for certain effort parameters, according to (Michalsik, Aagaard, et al., 2013; Michalsik, Madsen, et al., 2013)

Variables	Men (n=26)	Women (n=24)
Mean effective playing time (min.)	53.85 ± 5.87	50.70 ± 5.83
Total distance (m)	3627 ± 568	4002 ± 551
High-intensity running (% of the total distance)	7.9 ± 4.9	2.5 ± 1.8
Standing still (% of average actual playing time)	36.8 ± 8.6	10.8 ± 3.8
Sideways movement (% of average actual playing time)	7.4 ± 2.7	1.8 ± 1.3
Mean speed (km h^{-1})	6.40 ± 1.01	5.31 ± 0.33
Relative workload (% of estimated VO_{2max})	70.9 ± 6.0	79.4 ± 6.4
High-intensity technical playing actions (number)	36.9 ± 13.1	28.3 ± 11.0
VO_{2max} (mL O_2 min^{-1} kg^{-1})	57.0 ± 4.1	49.6 ± 4.8

The data presented in Table 4. 1, show significant differences in the amount of influence that energy systems have on the court activity of the two groups investigated. The results of this thorough research are contrasting and indicate that there are substantial differences specific to each gender. Boys are involved in more technical actions with maximum effort intensity, based on strength (anaerobic effort capacity), while girls prefer aerobic actions, managing to run more, at higher intensities of the maximum effort potential.

4.2. Anthropometric features in women's handball

From our observations, the most followed anthropometric parameters are: age, body weight, height, palm opening, arm span, adipose tissue index, etc. In Table 4. 2, we present some data, identified by us in the literature, which refer to the somatic peculiarities of the players who play in the elite competitions of international handball.

Table 4. 2. Summary of the somatic characteristics of handball players, from different international competitions, according to us

Study	Playing level	Players (no.)	Age (years)	Weight (kg)	Height (cm)
(Michalsik, Madsen, et al., 2013)	The Danish Handball Federation	24	25.9 ± 3.8	70.3 ± 7.4	174.2 ± 5.7
(Moss et al., 2015)	European National Teams	29	16.1 ± 1.3	71.8 ± 8.6	176.3 ± 6.6
(Karpan et al., 2015b)	HC Krim Mercator, Ljubljana, Slovenia	15	22.8 ± 5.354	73.7.± 7.837	180 ± 6.140
(Ferragut et al., 2018)	Royal Spanish Handball Federation	89	26.4 ± 4.5	70.6 ± 7.8	174.3 ± 7.7
(Noustos, 2018)	World Championship 2017	-	27.4 ± 3.5	68.8 ± 4.4	175.2 ± 5.0
(Wagner et al., 2020)	Champions League	11	25.7 ± 3.6	71.5 ± 9.4	174 ± 0.9

The comparative research carried out by us at the level of the Romanian national team, on the performances from the European Championship (2018) and the World Championship (2019) reveals that the somatic aspects were not a major factor influencing the place obtained at the end of the two competitions, but rather, what mattered was the level of experience of the players (Gheorghe and Mereuță, 2020). According to the values highlighted in Table 4. 3, we can see that between the two teams selected for the two competitions there were significant differences only in the case of the number of international matches and goals scored. We can say that the low level of experience influenced the ranking on the 12th position at the World Championship (2019), although a year before Romania had obtained the 4th place at the European Championship (2018).

Table 4. 3. Somatic and performance differences concerning the Romanian team, between EHF EURO 2018 and IHF CM 2019

Indicator	EHF EURO 2018	IHF CM 2019
Age (years)	26.8	25.8
International matches (%)	37.7	51.6
Goals scored (n)	73	116
Height (cm)	178	178
Weight (kg)	72	70
Position	**4**	**12**

4.3. Biomotor aspects in women's handball

Adapting to the **biomotor stresses (biological or physiological and motor)** imposed by the effort specific to handball matches has always been a topic of interest among specialists. In 2018, 7.81% studies were identified on the topic of physiological adaptation and 7.03% studies on the measurement of physiological variables, following the extensive review of the literature (Saavedra, 2018).

Recently, a team of foreign researchers (Wagner et al., 2020), successfully developed and implemented one of the only tests based on the simulation of an official handball match, after which they were able to investigate the physical and physiological performance of three target groups of players, differentiated in value as follows: the first group of 10 **elite** women players in the Austrian championship; group 2 of 11 **top elite** players in the Danish championship and group 3 of 11 **world class** players (members of the national team of Denmark).

Table 4. 4. Differences between elite, top elite and world class players, in terms of selected effort parameters, according to Wagner et al. (2020), adapted by us

Variables	Elite	Top elite	World class
Age (years)	20 ± 5	24 ± 3	26 ± 4
Height (cm)	1.69 ± 0.05	1.75 ± 0.06	1.74 ± 0.10
Weight (kg)	63 ± 6	72 ± 9	72 ± 9
Shot velocity ($m \cdot s^{-1}$)	21.0 ± 1.3	23.0 ± 1.6	23.4 ± 1.5
Fast break (s)	4.22 ± 0.20	4.25 ± 0.22	4.02 ± 0.20
Turnover (s)	2.17 ± 0.12	2.29 ± 0.20	2.18 ± 0.15
Acceleration (s)	2.11 ± 0.09	2.05 ± 0.13	1.96 ± 0.09
Jump height (m)	0.30 ± 0.06	0.32 ± 0.06	0.31 ± 0.05
Blood lactate ($mmol \cdot L^{-1}$)	9.9 ± 1.5	10.5 ± 2.7	9.0 ± 2.9
VO_{2max} (mL O_2 min^{-1} kg^{-1})	54.2 ± 2.9	60.06 ± 4.8	64.3 ± 6.4
FC_{max} (ppm)	195 ± 9	188 ± 6	182 ± 12

According to the data in Table 4. 4, the shot velocity in the case of the studied athletes ranges between 21.0 ± 1.3 m/s and 23.4 ± 1.5 m/s. The average time recorded on the fast break phases was 4.02 ± 0.20 s in the case of the world class group and on turnover 2.17 ± 0.12 s, in the case of the elite group. Regarding the jump (hence the anaerobic power), the best result was obtained by the players in the middle category (0.32 ± 0.06 m).

Regarding lactic acid, the values obtained vary between 9.0 ± 2.9 $mmol \cdot L^{-1}$ and 10.5 ± 2.7 $mmol \cdot L^{-1}$. Regarding the results of aerobic metabolism (VO_{2max} and FC_{max}), there are significant differences between the three target groups and we observe a better efficiency of the cardiorespiratory system in conditions of effort specific to handball matches, in the case of world-class players (64.3 ± 6.4 mL O_2 min^{-1} kg^{-1}).

The identified studies reported averages of intensity during women's handball matches of 86% of FC_{max} (Manchado et al., 2013) and of 84.4 ± 5.1% FC_{max} (Kniubaite et al., 2019), while the averages of the teams studied for FC_{max} can reach 191.1± 8.417 ppm (Karpan et al., 2015b), 162 ± 8 ppm (Michalsik, Madsen, et al., 2013), 195 ± 9 ppm at the elite level, 188 ± 6 ppm at top elite level and 182 ± 12 ppm at world class level (Wagner et al., 2020).

Some researchers have classified the actions of maximum intensity (AIM) in accelerations, decelerations and changes of direction and followed their occurrence by positions, during 9 official matches in the Golden League competition of 2014/2015 (Luteberget & Spencer, 2017).

Table 4. 5. Classification of actions of maximum intensity, according to positions (average and standard deviation), according to Luteberget & Spencer (2017)

Event	Wing	Back	Pivot	Total
Accelerations	0.51 ± 0.28	0.90 ± 0.35	0.68 ± 0.16	0.7 ± 0.4
Decelerations	0.76 ± 0.20	1.22 ± 0.34	1.24 ± 0.41	2.3 ± 0.9
Changes of direction	1.97 ± 0.73	2.90 ± 0.65	2.22 ± 0.45	1.0 ± 0.4

It can be seen, according to Table 4. 5 that the court players achieved on average, per minute, 0.7 ± 0.4 acc./min., 2.3 ± 0.9 dec./min. și 1.0 ± 0.4 SdD/min. The differences between the playing positions were substantial, the most stressed positions being the back (0.90 ± 0.35 acc./min., 1.22 ± 0.34 dec./min. and 2.90 ± 0.65 SdD/min), followed by pivot (0.68 ± 0.16 acc./min., 1.24 ± 0.41 dec./min. and 2.22 ± 0.45 SdD/min) and then by the wings (0.51 ± 0.28 acc./min., 0.76 ± 0.20 dec./min. and 1.97 ± 0.73 SdD/min).

4.4. Quantifying the technical-tactical efficiency in the game of handball

Many specialists believe that the individual or collective efficiency in the game, in attack and defense, is a determining factor in sports performance (Foretić et al., 2013; Gruić et al., 2006; Manchado et al., 2013; Wagner et al., 2014) and depends largely on the factors that influence the performance of actions during matches: rules of the game, technique, tactics, court size, time and communication (Manchado et al., 2013).

The methodology for measuring and evaluating the efficiency of players involves first selecting the most relevant performance indicators from major competitions, which have been classified into match indicators, tactical indicators, technical indicators and biomechanical indicators (Hughes & Bartlett, 2002), depending on each phase of the game: positional attack, transition attack (second phase), positional defense and transition defense (turnover).

Our concerns regarding this subject materialized in an analysis of the collective efficiency on the attack phase of the Romanian team, at the last edition of the 2019 World Championship, in Kumamoto, Japan. Therefore, we present in Table 4. 6 a statistical comparison between the Romanian team and the medal-winning teams of the tournament, in terms of efficiency at completion and efficiency of attacks.

Table 4. 6. Comparison between the statistical data obtained by the Romanian team and the medal-winning teams at C.M. 2019

Team	Goals/Shots %	Goals/Shots %
ROMANIA (12th rank)	52%	42%
NETHERLANDS (1st rank)	60%	53%
SPAIN (2nd rank)	62%	52%
RUSSIA (3rd rank)	68%	57%

4.5. Psychological aspects in the game of handball

The analysis of the psychological factor and its influence on sports performance are topics approached with interest in recent decades, in all sports. In handball, however, there is little research conducted on the psychological profile of players.

As we have seen, high-performance sports practice has shown that players with motor, physiological, technical-tactical and mental abilities are successful at an increasing pace, unlike those who show deficiencies in physical, technical-tactical and even psychological training. Due to the complexity of the game of handball, a perfect balance between all the influencing factors seems to be the necessary foundation for reaching athletic shape in the most important moments of the competition, so as to obtain the best performance.

CHAPTER 5. ASPECTS CONNECTED TO WARM-UP PROCEDURES BEFORE EFFORT, IN HANDBALL COMPETITIONS

5.1. The role of warming up the body for effort, before sports competitions

The effects of warming up have been addressed in many specialized works on various sports (Anderson et al., 2014; Bishop, 2003a, 2003b; Gabbett et al., 2008; Mohr et al., 2004; West et al., 2016). According to these studies, going through a warm-up program can have the following physiological and psychological effects on the body of athletes:

- increase in body temperature to values of 38.5 - 39.5 degrees Celsius (°C) and muscle temperature;
- accelerating metabolic reactions that ensure the availability of O_2 resources and protecting anaerobic energy in the first minutes of exercise;
- intensifying the speed of muscle contraction by amplifying nerve impulses;
- increasing the O_2 uptake capacity;
- an increase in physical performance due to the activation of the large biological systems;
- a reduction of the risk of injury - injuries that occur within a team can remove important players from the competition, around which the game strategy is carried out.

5.2. Warming up the body for effort, before handball matches

Active warm-up before handball matches involves a set of exercises structured in two distinct parts: general warm-up and specific warm-up.

The *general warm-up* specific to the game of handball is composed of exercises without the ball, and consists in going through some variants of walking and running, which can be combined with exercises in basic gymnastics, acceleration and sprints over short distances (Ghermănescu, IK, 1983, p. 219).

The *specific warm-up* is the one adapted with the ball, which involves the repeated performance of the main elements, procedures and technical-tactical actions, specific to the game of handball.

5.3. Aspects related to the start of the match and the break between halves

The official handball matches take place over two halves, lasting 30 minutes, during which two opposing teams face each other on the court. The two halves are separated by a 10-minute intermission. During this time, the athletes are involved in various organizing activities (tactical discussions with the coach or colleagues, hydration, recovery, etc.), they go to the locker room. The break between the halves is the only opportunity for a re-warming-up of the players who have not played until then.

5.4. Strategies of re-warming up the body for effort

Performance strategies for the second half became essential as inactivity was associated with physiological changes (decreased body and muscle temperature, lower blood glucose, decreased heart rate) that resulted in decreased physical and mental capacity (Arslan et al., 2017; Lovell et al., 2013; Mohr et al., 2004).

In the literature, there are few studies that address the active recovery as a method of maintaining the benefits of initial warm-up for effort. The term re-warming up refers to the period immediately following a period of physical inactivity, in order to reactivate the body for effort.

Starting with 2018, several Japanese researchers set out to study the effects of re-warming up the body after a period of inactivity, by implementing protocols with different duration and intensity of effort, during the **intermission between halves** (Yanaoka et al., 2020, 2021; Yanaoka, Hamada, et al., 2018; Yanaoka, Kashiwabara, et al., 2018). Extensive research over the years has led to the conclusion that a one-minute, high-intensity reactivation (90% VO_{2max}), resulted in improved speed, increased body temperature, muscle activation, and increased heart rate without causing fatigue in the second half of matches (Yanaoka et al., 2021).

5.5. Fatigue during the handball match

A recent study by Michalsik et al. (2018) determined that handball players who accumulated more than 70% of the total playing time, showed signs of fatigue translated in a reduction of the number of maximum intensity activities by 21.9% between halves (44.9 ± 16.8 m in the first half, compared to 57.5 ± 21.3 m in the second) and a reduction in the average running speed from 5.34 ± 0.36 km·h^{-1}, during the first half, to 5.29 ± 0.34 km·h^{-1}, during the second. The same study reported differences in the total distances covered in the first half (2 010 ± 362 m), compared to the second (1 993 ± 382 m).

These results indicate that fatigue is accumulated progressively throughout the match and especially towards the end of it. Therefore, *many experts recommend that coaches use effective rotation strategies for players that could delay or reduce excessive fatigue by giving them time to recover*. In this way, efforts of maximum intensity and a high level of efficiency in the game could be sustained for a longer time.

5.6. Recovery after effort during the game of handball

Research in performance sports has focused mainly on recovery strategies used *after* the cessation of physical effort in order to maintain or improve performance from match to match. Moreover, recovery techniques during sports activities are under-exploited, particularly in the case of women's handball.

5.7. Passive recovery and active recovery in performance sports

In the literature, the recovery (active or passive) is also presented as rest, recuperation or recovery and it is a natural means of restoring the body, which can occur after or during physical exertion.

5.8. The effects of passive recovery

The effects of inactivity on substitute players have not been sufficiently investigated in performance handball. By expanding the research, we identified several studies conducted in the game of football, according to which the passive recovery between halves was associated with decreased running intensity and increased incidence of injury to players in the second half (Edholm et al., 2014; Hammami et al., 2018; Lovell et al., 2013; Mohr et al., 2004; Russell et al., 2015; L. M. Silva et al., 2018).

Studies in the game of basketball have reported *conflicting results of passive recovery on the body of athletes*. Two of them identified progressive decrease in the physical and physiological responses of athletes, following periods of inactivity. The research group Crowther et al. (2017) reveal that after only 6 minutes of passive recovery, the physiological results obtained by two athletes subjected to tests, indicated a decrease in body temperature (T_c) by ~0.5^{o}C and abdominal temperature (T_a) by ~2.0^{o}C, a return to baseline values of muscle temperature and heart rate, and after 20 minutes, the performance of the countermovement jump test (CMJ) decreased by 15% compared to that obtained after the match warm-up. These results confirm the 2012 findings of Galazoulas et al., who claimed that after 40 minutes of inactivity, the performance of athletes was reduced by 20% in the case of jumping and 6% in the case of running. Results suggest that a passive recovery can have a significant negative impact on explosive tasks such as jumping and speed acceleration at the beginning of sprints. Contrary to these findings, another basketball study recommends using the passive recovery during matches to the detriment of the active one. The results were recorded against the active recovery, as it was found that pedaling at an intensity of 30% of maximum aerobic capacity (VO_{2max}) led to decreased agility and faster installation of fatigue perceived by athletes.

5.9. The effects of the active recovery in other sports

Over the years, many researchers have argued that one of the most important benefits of active recovery after strenuous exercise is the faster elimination of residues from the blood, such as lactic acid. According to experts, lactic acid accumulated in the blood as a result of intense exertion can be eliminated by 62% in the first 10 minutes after effort and another 26% after the next 10 minutes, using moderate-intensity aerobic recovery exercises such as light jogging (Bompa & Buzzichelli, 2015).

Other older studies in performance sports have also shown positive results after using the active recovery compared to the passive one. They claim that after submaximal and maximal exertion, pedaling at intensities between 30-70% of $VO2_{max}$ reduced the accumulation of lactic acid in the blood and the development of greater anaerobic explosive strength than by using passive recovery (Gisolfi et al., 1966; Hermansen & Stensvold, 1972; Dodd et al., 1984; Ahmaidi et al., 1996).

A study in gymnastics reveals that a combination of active and passive recovery is beneficial to the elimination of lactic acid and to the performance of gymnasts during competitions (Jemni et al., 2003). These results contradict the study on hockey (Spierer, 2004), which revealed that the active recovery (28% of VO_{2max} intensity) did not help the faster elimination of lactic acid from the blood, the differences being insignificant (2.0 ± 0.3 to 14.8 ± 0.9 mmol/l^{-1} active vs. 1.6 ± 0.1 to 15.5 ± 0.9 mmol/l^{-1}passive).

One of the few studies on handball (Arazi et al., 2012) confirmed that lactic acid is eliminated more quickly from the blood after exertion, by using various means specific to the active recovery (running, jogging), at intensities between 55-70% FC_{max}. On the other hand, some researchers point out that the active recovery used at high intensity can compromise the ability to perform successive runs at high intensity and can lead to muscle deoxygenation in handball players (Buchheit, Cormie, et al., 2009).

Negative results of the use of the active recovery were also recorded in athletics. It was found that the active recovery can speed up the time to exhaustion in intermittent runs with short breaks between them. As a result, active recovery between tests involving successive maximum effort is not beneficial (Dupont et al., 2003). On the other hand, another study in athletics identified positive effects in the elimination of lactic acid, through the use of myofascial massage, foam roller and high-intensity pedaling of 40% FC_{max} (Özsu et al., 2018). Three types of recovery were used: foam roller massage, active recovery by pedaling and passive recovery by standing, with the aim of determining the effects of the 3 types of recovery on the elimination of lactic acid and on the quality of total recovery of athletes. The results are contrasting: massage and active recovery were more effective in eliminating lactic acid, but a better quality of total recovery was observed with foam roller massage, than with the other two methods.

Very few studies have investigated the effects of passive or active recovery on the efficiency in team sports. Most of the research mentioned is focused on the physical and physiological evaluation of the players and, so far, we have not been able to identify studies that propose an adequate protocol for evaluating and quantifying the technical-tactical efficiency in the game, after both recovery conditions, by the court side.

CHAPTER 6. CONCLUSIONS AND THE NOVELTY OF THE STUDY'S THEORETICAL ASPECTS

- Efficiency in the game (individual and collective) is considered one of the most important factors in sports performance,
- Restoring the body by restoring energy potential and functional capabilities during matches can only be achieved through an optimal ratio of effort and rest that is possible by the efficient rotation of players. Therefore, many experts recommend that coaches use effective rotation strategies of players that could delay or reduce excessive fatigue.
- The few studies that evaluated the performance of substitute athletes after the period of inactivity on the margins, are oriented towards the physical and physiological evaluation of athletes. These reported significant decreases and even a return to baseline functional indexes essential for the proper functioning of major biological systems and functions (heart rate, temperature, anaerobic power), the effects being directly proportional to the duration of inactivity. Decreased body and muscle temperature is considered to be the main reason for the regression of athletes' physical performance in all studies that have investigated the effects of passive recovery.
- Handball studies on the effects of passive recovery and the use of active recovery are very small and are aimed at men's handball.
- There are no studies in women's handball that suggest strategies for rotating players in order to reduce fatigue and maintain performance in the game.
- There are very few studies in all team sports in general and women's handball in particular that assess the efficiency of players on the court after a period of inactivity.
- **Very few studies have investigated the effects of passive or active recovery on efficiency in team sports. So far, we have not been able to identify studies that would propose an adequate protocol for evaluating and quantifying the technical-tactical efficiency in the game, after going through both recovery conditions on the edge of the court.**

PART II: PRELIMINARY RESEARCH ON THE EFFECTS OF THE PASSIVE RECOVERY AND THE APPROPRIATENESS OF USING ACTIVE RECOVERY ON THE EDGE OF THE HANDBALL COURT

CHAPTER 7. THE METHODOLOGICAL OPERATIONAL APPROACH OF THE PRELIMINARY RESEARCH

7.1. Prerequisites for preliminary experimental research

In defining the premises for the preliminary research, we started from an organizational detail of handball matches, i.e. all players who are not part of the starting teams, are required, by regulation, to sit on the bench, in sitting position until they are introduced on the court. Following and analyzing the trends of the modern handball game, to which we add the theoretical knowledge derived from the specialized literature, in accordance with the proposed topic, permit us to start the preliminary research starting from the formulation of the following **prerequisites**:

- Harnessing the potential of all players on a team is an innovative, current strategy in modern handball and can be a major factor in influencing sports performance when used properly.
- Effective management in the rotation of a handball team's players during matches can reduce or delay the onset of handball-specific fatigue, so substitute players must be optimally prepared for these changes.
- *The passive recovery imposed on the edge of the court, immediately after the warm up leads to the diminution and even the cancellation of the effects of the warm up, from a physical and physiological point of view since the substitute players entering the match must respond immediately and in an optimal way to the physical and technical-tactical demands specific to the game of handball.*
- *The inadequate effort capacity of players entering the game after a period of passive recovery can negatively influence their technical and tactical evolution and can lead to low performance in the game.*
- Efficiency (individual and collective) is a key factor in high-performance handball, with a major influence on the evolution of the game, the result at the end of the game and the place in the ranking of various competitions.
- The experience and training of the responding coaches credit the answers obtained regarding the effects of the passive recovery and the possibility of replacing it with an active recovery program and paint a clear picture of the necessity to maintain the benefits of warm-up for substitute players in the eventuality of their exchange with court players during the match.

7.2. Objectives of the preliminary experimental research

- ✓ *The analysis of the opinion of the specialists in the field of handball, regarding the need to replace the passive recovery on the edge of the court, with an active protocol, to maintain an optimal physical condition for entering the court at any time of the match.*
- ✓ *Determining the maximum effort capacity by relating the value of the maximum heart rate (FC_{max}) and the maximum oxygen uptake (VO_{2max}).*
- ✓ *Physical, physiological and technical-tactical evaluation through tests and tools specific to each evaluation, in conditions of passive recovery, during training and training matches, controlled by us.*
- ✓ *Investigation of some indicators that refer to the motor performance and to the technical-tactical behavior of the players, after the implementation of the passive recovery, in a series of bilateral handball playing sessions, lasting 15 minutes.*
- ✓ *Optimizing the research methodology by checking the data recording tools.*
- ✓ *Determining a set of methods and means for objectively quantifying the in-game efficiency of female athletes.*
- ✓ Investigating the evolution of the values of some physical indices by tests performed *before and after the implementation of the passive recovery*, as

follows: after the warm-up for the match, i.e. before the implementation of the passive recovery (T1 PP) and after the implementation of the passive recovery (T2 PP).

- ✓ Investigating the evolution of the values of some physiological indices by tests performed *before and after the implementation of the passive recovery*, as follows: before warm up, in the locker room (Tv), after the match warm up, i.e. before the implementation of the passive recovery (T1 PP) and after the implementation of the passive recovery (T2 PP).
- ✓ Investigating the existence of statistically significant correlations between the body's physical and physiological level of preparation for effort and the motor and technical-tactical performance of the players during handball matches.
- ✓ Investigating the link between changes in the values of physical and physiological indices after physical inactivity and the performance of players on the court.
- ✓ Processing and interpreting the data recorded after the preliminary study, in order to perform the primary experiment, leading to the development and implementation of a protocol to maintain optimal parameters of the body's ability to function, in order to improve the performance in the game, of the players who are exchanged.
- ✓ Formulation of conclusions and recommendations.

7.3. The purpose of the preliminary experimental research

The diversity of the proposed tests and the complexity of the preliminary experiment determined the following **aims** for the current research:

1. *Identifying the effects of standard match warm-up on physical and physiological indices of the body, to discover the latter's level of preparation for subsequent efforts.*
2. *Identifying the need for primary experimental research and outlining the course of action to replace the passive recovery with an active recovery protocol, based on knowing the effects of inactivity on the benefits obtained by warming up for the match and based on the opinion of specialists in the field of our research.*
3. *Discovering the details related to the performance of the players during the match, when entering the court after 15 minutes of passive recovery.*
4. *Identifying significant associations between the body's level of readiness for effort and the performance of court players.*
5. *Verifying of unconventional methods and means of calculating and monitoring of players' results, proposed for use in the evaluation protocols.*

7.4. The tasks of the preliminary experimental research

1. Scientific documentation focused on sources in the field of sports medicine, handball game methodology, as well as in the field of sports technology.
2. Identifying the new trends in the game, for performance handball, knowing the criteria and their applicable limits as well as analyzing the current regulations of the handball game in Romania.
3. Selecting the subjects and specialists involved in the research and planning the research stages.
4. Learning the weekly training plan established by the team coach and the competition program proposed by the Romanian Handball Federation.
5. Determining the premises and elaborating the hypotheses of the preliminary experimental research.
6. Elaborating a questionnaire, to investigate the opinions of the specialists in the field, regarding the topic approached in our research.
7. Elaborating observation sheets to record the degree of individual and collective efficiency according to the shot percentage during official matches.
8. Choosing a method for calculating FC_{max}, based on information from the specialized literature and field tests.
9. Developing protocols for evaluating players through physical and physiological tests, during training and training matches, controlled by us.

10. Choosing a series of unconventional methods and means of evaluation, at different times of testing, to provide relevant information on the evolution of physical and physiological indices and their influence on court performance, under conditions of passive recovery.
11. Recording the values of the physical indices after the warm-up for the match by applying the physical evaluation based on specific tests and investigation tools.
12. Recording the values of the physiological indices before the effort, after the warm-up for the match and after the period of inactivity, by applying the physiological evaluation based on the specific tests and investigation tools.
13. Recording and highlighting the changes effected by 15 minutes of passive recovery on the values of physical and physiological indices and comparing them with the values obtained after the match warm-up.
14. Elaborating a calculation formula that would quantify the overall efficiency in the game, according to the standardized actions and the individual physiological peculiarities and that would help provide objectivity to the process of technical-tactical evaluation of the handball players.
15. Calculating the efficiency of the players based on the implementation of the developed formula and compiling a database with the results recorded by the athletes following a 15-minute playing half, under conditions of passive recovery.
16. Processing and interpreting the data obtained from the social survey.
17. Processing and interpreting of data obtained from physical and physiological court edge assessments and from assessing motor and technical-tactical efficiency on the court.
18. Formulating the conclusions of the preliminary experimental research.

7.5. Preliminary experimental research hypotheses

The hypotheses tested in the preliminary experimental research are as follows:

- 🕮 **H1**. The application of the opinion poll helps to obtain an information base necessary to identify the necessity to eliminate the passive recovery and replace it with an active recovery protocol on the edge of the handball court, given the global trend to exchange players among them, to avoid physical overload and to maintain a high level of play throughout the match.
- 🕮 **H2.** The identification, analysis and comparison of the individual offensive efficiency of the court players, of the team under study, with the results of the efficiency obtained at the level of the position and of the team, provides information on the efficiency differences between on court and substitute players, as well as on the weaknesses of the team according to position.
- 🕮 **H3.** Determining the maximum effort capacity in relation to the value of the maximum heart rate (Fc_{max}), using court tests, will provide important data in order to perform the calculations necessary for the subsequent application of an innovative formula to quantify the efficiency in the game. At the same time, learning the maximum aerobic capacity provides the opportunity to correctly direct the intensity of the effort within the primary experimental research.
- 🕮 **H4.** Passive recovery in the sitting position on the bench will decrease muscle activity, which will lead to decreased performance in tests involving explosive physical tasks, an aspect which is revealed by the **physical** assessment after 15 minutes of complete passive recovery in a sitting position, on the substitute benches (moment T2 PP).
- 🕮 **H5.** The passive recovery will cause the heart rate and body temperature values to decrease as a result of inactivity in the sitting position on the substitute bench for 15 minutes, which is revealed by the **physiological** assessment after 15 minutes of complete passive recovery, in seated position, on the substitute benches (moment T2 PP).
- 🕮 **H6.** The passive recovery will cause the accumulation of lactic acid in the blood, due to inactivity in a sitting position on the bench, for 15 minutes, after the end of the physical effort specific to the match warm-up, aspect revealed by the **physiological** evaluation after 15 minutes of complete passive recovery, in a seated position, on the substitute benches (moment T2 PP).

- **H7.** The passive recovery following the warm-up for the match will have no effect on the indices of serum glucose or blood oxygen saturation, an aspect revealed by the **physiological** evaluation after 15 minutes of complete passive recovery, in a sitting position, on the bench (moment T2 PP).
- **H8**. The on court evaluation will provide relevant information about the **motor and technical-tactical potential** of the players, when entering the match after 15 minutes of passive recovery, in a seated position on the bench.
- **H9**. The calculation formula developed to quantify the overall efficiency in the game will offer the possibility to adapt the evaluation process, to take into account the individual physiological and technical-tactical potential.
- **H10**. The level of preparation of the body for the effort specific to the game of handball is significantly associated with the court performance of the players when they enter the court from the substitute position.

7.6. Research methods used in the preliminary experiment

- Documentation/Literature review.
- Pedagogical observation.
- Social survey.
- Video analysis.
- Experiment.
- Measurement and evaluation.
- Statistical-mathematical analysis.
- Graphical representation.

7.7. Tests performed to determine the maximum aerobic capacity, before implementing the preliminary experimental protocol

7.7.1. The 30-15 IFT Test

30-15 Intermittent Fitness Test ($30–15_{IFT}$) was applied in our study to identify the maximum oxygen uptake (VO_{2max}) and the maximum heart rate (FC_{max}), the main indicators used to assess the maximum aerobic capacity.

The test protocol involves shuttle runs, with a fixed duration of 30 s, interspersed with an active recovery of 15 s, and the subjects must reach the demarcations placed at 20 m from one other, on a distance of 40 m. The test starts from a speed of 8 km/h, which increases by 0.5 km/h at each stage (so stage 1 = 8 km/h, stage 2 = 8.5 km/h, stage 3 = 9 km/h, etc.). The start and stop signals are dictated by the audio system of the program and the subjects run until they no longer reach the specially placed cones, three times in a row. The last stage also establishes the maximum running speed (V_{IFT}) obtained by the subjects at exhaustion, an essential indicator for calculating the maximum oxygen uptake.

Buchheit, M. (2005) developed a simple but indirect method of calculating VO_{2max}, which is highly valued and used in all sports that involve intermittent effort and is expressed by the following formula[5]:

$$VO_{2max}\,(ml \cdot kg^{-1} \cdot min^{-1}) = 28.3 - (2.15 \cdot S) - (0.741 \cdot V) - (0.0357 \cdot G) + (0.0586 \cdot V \cdot V_{IFT} + 1.03 \cdot V_{IFT}$$

Where:

($ml \cdot kg^{-1} \cdot min^{-1}$)=milliliters consumed per minute, per kilogram of body weight at maximum performance;
S= subject gender (female = 2; male = 1);
V= age;
G= weight;
V_{IFT}= running speed recorded in the last stage.

[5] Buchheit, M., Simon, C., Charloux, A., Doutreleau, S., Piquard, F., Brandenberger, G. (2005). Heart rate variability and intensity of habitual physical activity in middle-aged persons. *Med Sci Sports Exerc*, *37*, 1530–1534.

7.7.2. On-court tests through friendly competitive games

One of the directions of our preliminary research was to learn the evolution of individual heart rate during friendly handball matches, because it has the advantage of putting players in situations similar or identical to those assumed by official matches.

In this sense, we aimed to identify the values of heart rate by means of Garmin Fenix 5S smart watches, during the two friendly matches held on the court of the CSM Galați team, in the company of the Gloria Buzău team. The matches were recorded with the help of a video camera and the data on the technical-tactical behavior of the players were collected by later viewing the recordings and scoring them on the individual charts.

The FC monitoring clocks were distributed to the locker room, where the resting FC value was noted on the individual sheets (Figure 7. 1).

Figure 7. 1. Garmin Fenix 5S watches and registration sheets, ready for distribution, in the locker room of the CSM Galați team

The data was stored in the internal memory of the clocks, which were then synchronized with the Garmin Connect application on the laptop we used in the research. Once synchronized, the data was downloaded and analyzed for this stage of our preliminary experiment.

7.8. The battery of tests used for physical evaluation, during the preliminary experimental protocol

7.8.1. Tests to assess maximum anaerobic capacity, explosive power and acceleration speed before and after the implementation of the passive recovery protocol

Jump tests are considered relevant methods for determining the neuromuscular function in the lower limbs. Nowadays, with the help of modern technological measuring instruments, researchers can capture the performance of athletes in vertical jump tests by monitoring the various variables of effort. In addition to the classic indices such as jump height or flight time, it is possible to identify the average and maximum values of the power or speed indices. Another valuable index is the RSI-reactive strength index which represents the ratio between the height of the jump and the time of contact with the ground and provides important information about the degree of adaptation to effort or fatigue (McMahon et al., 2017).

For specialists in the field, tests to assess reactive strength are effective methods for determining the state of fatigue, starting shape or the athletes' level of adaptation to training or competition processes.

The indices analyzed in the *anaerobic power* assessment tests depend to a large degree on the test instruments, but, generally, the jump height, flight time, ground contact time, power or acceleration indices, etc. are monitored.

7.8.1.1. The countermovement jump (CMJ)

CMJ is evaluated with or without additional load and it is used as an exercise in training for the development of strength in the lower body, but many specialists (coaches, trainers, researchers) use it as a *method in batteries of tests to assess power or level of neuromuscular fatigue*. CMJ is a simple, valid and practical method for measuring power in the lower limbs and it is also the most used method by comparison to other jump tests.

Its validation and use have been successfully achieved in sports that require players to have higher reactive strength indices, such as football (Wisloff et al., 2004), rugby (Waldron et al., 2013), basketball (Crowther et al., 2017; Galazoulas, 2012), volleyball (Charlton et al., 2016; Lima et al., 2019) or handball (Karcher & Buchheit, 2014; Vukadinović Jurišić et al., 2020).

The CMJ jump received its name because the starting position involves performing a movement, before detachment from the ground, manifested under the form of rapid semi-flexion (against the movement that follows it), from a standing position with feet apart at shoulder width, arms on hips (Bobbert et al., 1987).

The CMJ jump **variants** are numerous but the most often used are *CMJ with arms fixed, CMJ with arm swing, single leg CMJ or RSI 10/5.*

7.8.1.2. The squat jump (SJ)

Another test for assessing the reactive strength in the lower limbs is the squat jump (SJ). In contrast to CMJ, SJ presupposes lowering and holding for three seconds in a semi-squat position and then detaching from the ground.

Figure 7. 2 gives details about the different body positions during CMJ and SJ. Another difference between the two types of jumps is the goal. There are researchers who claim that the CMJ assesses the ability to produce explosive strength during movements that involve both eccentric and concentric contractions, while the SJ assesses the ability to produce explosive strength only during concentric movements (Van Hooren & Zolotarjova, 2017).

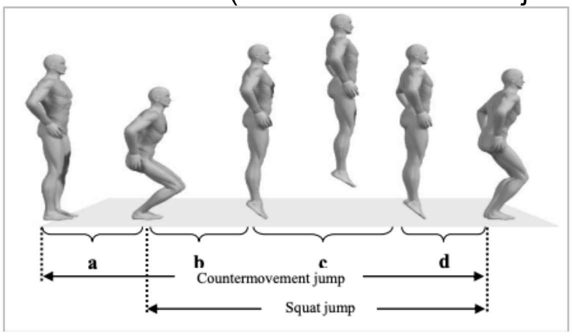


Figure 7. 2. Body position during CMJ (a, b, c, d) and during SJ (b, c, d), image from Alptekin et al. (2017)[6]

7.8.1.3. The reactive strength index 10/5

Another variant for determining the reactive strength in lower limbs is the test of successive jumps on both legs, RSI 10/5, which was invented by Harper et al. (2011)[7]. For this test, subjects must perform a CMJ jump, but at the time of landing, instead of stopping, they will continue to jump successively, 10 times, on both legs. At the end, the best 5 jumps are averaged and the total score is provided. RSI is expressed as the ratio of jump height (JH) to ground contact time (GCT) and it is measured in meters per second (m/s).

7.8.1.4. Throwing the 3 kg medicine ball (AMM)

The most important parameter for evaluating performance in AMM is the maximum throwing velocity (peak velocity- PV), that is recorded when the ball is released from between the hands.

Figure 7. 3 represents the phases of throwing the medicine ball to the wall and recording the results with the PUSH tape attached to the athlete's forearm. Athletes will start sitting sideways against the wall, with their left/right shoulder in front and the medicine ball held in both hands. An explosive twist of the torso follows and throwing it against the wall. The test is performed 3 times and the best result is recorded.

[6] Alptekin, A, Arıtan, S, Harbili, E. (2017). Investigation of Joint Reaction Forces and Moments During the Countermovement and Squat Jump. Pamukkale Journal of Sport Sciences, 8 (3), 58-71.

[7] Harper, D.; Hobbs, S.; Moore, J. The 10 to 5 repeated jump test. A new test for evaluating reactive strength. In Proceedings of the British Association of Sports and Exercises Sciences Student Conference, Chester, UK, 12–13 April 2011.

Figure 7. 3. Medicine ball side throw (screen captures by us), from video sources www.trainwithpush.com

During handball matches, the accuracy of shots at the goal was associated with increased efficiency in the game, being influenced by factors such as physical and anthropometric characteristics (Baştiurea et al., 2014; Ferragut et al., 2018; Hermassi et al., 2021; Saavedra, Kristjánsdóttir, et al., 2018), balance capacity or the ability to throw accurately under conditions of explosive strength (Raeder et al., 2015).

7.8.2. The 10-meter acceleration test

We used this test in our research to evaluate the acceleration speed. We chose to evaluate the performance of the players through this test because, after reading the literature we found that *during a handball match a player is involved in a number of approximately 663.6 ± 99.7 actions of different intensity* (Michalsik, Madsen, et al., 2013), and the most demanding actions involve accelerations (acc.), decelerations (dec.) and changes of direction (SdD), over short distances. Therefore, we believe that this test will be useful in revealing the players' ability to accelerate, in similar conditions of play, over short distances, to the detriment of the classic 30m sprint test in a straight line. For the organization of the 10-meter acceleration test the necessary materials are composed of chronometer, marker cones, roulette and registration sheets.

7.9. The battery of tests used in the physiological evaluation, as part of the preliminary experimental protocol

7.9.1. Heart rate investigation (FC)

Heart rate (FC) is often used as an indicator of athletes' reaction to effort, being just one of the body's many reactions to physical activity (Bompa, 2002, p.71). Measuring FC_{max} is preferred among researchers in most sports because it is a much simpler procedure than determining VO_{2max}. The use of FC_{max} is essential in knowing and determining the intensity of effort in training programs; there are currently several formulas for estimating it (if it cannot be determined directly). The best known is the Karvonen formula: FC_{max}= 220-the age of the subject (Karvonen et al., 1957). This was developed following an extensive study to measure FC values during specific tests and a standard deviation of 10-12 ppm is estimated. Other studies suggest that the Karvonen formula is incomplete as it does not include other important factors such as the age of the subjects, gender or level of activity (Londeree & Moeschberger, 1982).

In our research we wanted to monitor the internal stresses of the players by recording the FC values at different times of the experiment: at rest, during the effort and after the effort.

7.9.2. Temperature measurement

An increase in body temperature is one of the first effects of physical exertion and has been associated with better performance capacity. The body temperature is initially changed by following the warm-up protocol performed before any sporting activity, reaching normal values, at rest, of 36.3 - 37.5 degrees Celsius (°C), to values of 38.5 - 39.5°C, after warm-up (Bishop, 2003a).

Increasing muscle temperature is one of the functions of skeletal muscle (Enoiu, 2009) and it involves the production of heat following the ATP split, in addition to the energy needed for muscle contraction. Bishop et al. (2003) consider that the benefits of increasing muscle and body temperature translate into decreased muscle and joint stiffness, increased oxygen supply to muscles, improved anaerobic metabolism, or optimized speed of muscle contraction.

In performance sports, studies have identified a strong correlation between decreased body temperature and decreased athletic performance in jumping and speed tests (Galazoulas, 2012; Mohr et al., 2004).

7.9.3. Investigation of biochemical parameters: glycemia and lactic acid

Glycemia is the level of *glucose in the blood* and it is the body's main source of energy. Its investigation in sports can be done in order to identify the impact of physical effort on the body of athletes.

The study of *lactic acid* (lactacidemia) is a way to determine the intensity of the body's stress in order to direct training. The analysis of lactate can provide accurate information about the endurance and fatigue of athletes. Lactic acid values below 2 mmol/l are considered to be low (below 50% of the subject's maximum aerobic possibilities), while an increase of up to 4 mmol/l indicates that the maximum aerobic possibilities are reached (anaerobic threshold).

A decrease in the AL concentration in the blood during regular training or competitions indicates a good adaptation to effort and a better level of training, while an increase in the concentration of AL for the same type of activity demonstrates a decrease in the athlete's effort capacity (Bangsbo et al., 1996).

7.9.4. Investigation of oxygen saturation in the blood (SpO_2)

This test is important in sports activities to determine the state of fatigue. Normal values attributed to blood oxygen saturation are concentrations above 95%, but according to a recent study, a new threshold of normality of 97% is recommended (Elder et al., 2015). Values below this threshold may suggest certain afflictions or fatigue.

7.10. On-court evaluation (motor and technical-tactical), during the preliminary experimental protocol

7.10.1. Evaluation of motor performance

7.10.1.1. Total distance covered (km) and running speed (km/h)

The most important effort specific parameters for the game of handball are **volume and intensity**. In team sports, such as handball, the volume is estimated by the units of time and distance and the intensity is measured by exercise, either by the units of power (watt, kilograms/ minute), of speed (meters/second or kilometers/hour), or by the rate/minute of a movement's execution. Another method of measuring the intensity of the effort is by using the percentages of the maximum intensity, where 100% means the maximum potential.

Our research involved recording the total distance covered and the running speed during the 15-minute fixed sessions using the Garmin Fenix 5S watches.

7.10.2. Evaluation of technical-tactical efficiency

In order to develop a complex and objective method of quantifying the efficiency of the game, it was necessary to identify, **extract** and **standardize** quantitative indicators that reflect the array of *technical-tactical actions* of the players, depending on their positions. In addition, we aimed to identify and standardize the *positive actions (Ap.) and the errors (G.)* made by handball players during matches and assign values for these actions according to their importance in the game economy.

Our model is based on the one proposed by Alexe, N. (1993, pp.142-148) for determining the global efficiency coefficient (C.G.E.) calculated for standardized means of training, in freestyle wrestling, according to the following formula:

$$C.G.E. = C.S. \times C.U.$$

Where C.G.E.= global efficiency coefficient; C.S. = strain coefficient; C.U. = utility coefficient.

Our intervention on this model consisted in calculating the coefficients for *standardized technical actions during the offensive phase during matches (A.T.S.J.)* and *not for standardized means during training*. In addition, we considered it important to include in the calculation the *standardized positive actions in the game (Ap.S.J.)* and *the standardized errors in the game (G.S.J.)*. All these variables will ultimately reflect the efficiency of a handball player, *relative to the playing time available*.

7.10.2.1. Calculating the strain coefficient (C.S.)

The strain coefficient for each standardized technical action in the game (A.T.S.J.) specific to each player was calculated after recording the heart rate (FC) values during the two friendly matches organized by us, in the company of the Gloria Buzau team, when the players participating in the research wore Garmin Fenix 5S watches throughout the game.

Subsequently, FC values were associated with each A.T.S.J. performed by each player (step 3, shown below).

Step 1: Creating the list of records by position, based on the logical-pedagogical selection, of the standardized technical actions that refer to the situations in which the players are in possession of the ball. Thus, following the professional experience gained and the numerous viewings of the great international competitions, we identified 7 A.T.S.J. for the wing position (left and right), 7 A.T.S.J. for backcourt positions (left back and right back, center) and 6 A.T.S.J. for the pivot position.

Step 2: drawing a table (Table 7. 1) with 4 columns as follows:

- in column I- the current number of A.T.S.J.;
- in column II- standardized technical actions in the game (A.T.S.J.);
- in column III heart rate (FC) recorded at the time of the respective action;
- in column IV- the values of the strain coefficient (C.S.)

Table 7. 1. Cumulative table of heart rate (FC) and strain coefficient (C.S.) values for C.L. player on the left wing

Calculating the coefficient of strain LEFT WING- C. L.			
No.	A.T.S.J.	FC (ppm)	C.S.
1.	A.T.S.J. 1- Shot on the fast break/phase II (A.C./A.F2);	181	1
2.	A.T.S.J. 2- Position angle shot (A.P.)	170	0.94
3.	A.T.S.J. 3- 6-meter line breakthrough shot (A.6m)	164	0.91
4.	A.T.S.J. 4- Position shot after overtake (A.P.D.)	170	0.94
5.	A.T.S.J. 5- 9 m crossing shot (A.Î.9m)	171	0.94
6.	A.T.S.J. 6- 7-m shot (A.7m)	168	0.93
7.	A.T.S.J. 7- Empty net shot (A.P.G)	160	0.88

A.T.S.J.= standardized technical actions in the game; F.C. = average heart rate after 2 friendly matches; C.S.= strain coefficient.

Step 3: Marking down on the individual sheets the FC recorded by G.F.5.S clocks, at the time of each standardized technical action in the game. This stage occurred after downloading the data recorded during the two friendly matches organized by us.

Example 1: The player in Figure 7. 4 is involved in the standard action of shooting from the position, from an angle (A.T.S.J. 2), at a certain time during the friendly match. By stopping the video, we identified the moment of the shot (min: 15:47) and associated it with the estimated FC value in 15:47 minute of the Garmin Fenix 5 S watch (Figure 7. 5) that the player was wearing on her wrist in this match.

Figure 7. 4. The C.L. player (left wing), making a position angle shot, in minute 15:57 of the friendly match

Figure 7. 5. The value of the heart rate estimated by the Garmin Fenix 5S watch in the minute 15:57, associated with the position angle shot of the C.L. (left wing) player, image taken from the personal account on Garmin Connect portal

Step 4: After recording the FC associated with the execution of all A.T.S.J., the maximum value of the FC is highlighted, which becomes a **standard** in the calculation of the stress coefficient. The values are filled in the individual sheets created for each player included in the research (Table 7. 2).

Step 5: Calculating the strain coefficient (C.S.) for each standardized technical action in the game (A.T.S.J.), in the case of each player included in the experiment, according to the position occupied, using the formula:

$$C.S. = \frac{FC of A.T.S.J. given}{FC standard}$$

Spreadsheet template for the strain coefficient (C.S.), WING

Table 7. 2. The strain coefficient for left wing C.L.

Strain coefficient calculations LEFT WING.- player C.L.			
No.	Standardized technical action in the game (A.T.S.J.)	FC (ppm)	C.S.
1.	A.T.S.J. 1- Shot on the fast break/phase II (A.C./A.F2);	181	1
2.	A.T.S.J. 2- Position angle shot (A.P.)	170	0.94
3.	A.T.S.J. 3- 6-meter line breakthrough shot (A.6m)	164	0.91
4.	A.T.S.J. 4- Position shot after overtake (A.P.D.)	170	0.94
5.	A.T.S.J. 5- 9 m crossing shot (A.Î.9m)	171	0.94
6.	A.T.S.J. 6- 7-m shot (A.7m)	168	0.93
7.	A.T.S.J. 7- Empty net shot (A.P.G)	160	0.88

A.T.S.J.= standardized technical actions in the game; F.C. = average heart rate after 2 friendly matches; C.S.= strain coefficient.

7.10.2.2. Calculating the utility coefficient (C.U.)

The utility function plays an important role in the evaluation of the players subject to our research, because it solves a complex problem encountered in handball matches, that of objective classification of standardized actions in the game in terms of their importance in the game economy, as well as of the strain degree, while also taking into account that they differ depending on the position held in the team.

Establishing the values of the *utility coefficients* can be determined by each coach/specialist, depending on the potential of the players in the team he/she leads.
Step 1: idem step 1 from the calculation of the strain coefficient**.**
Step 2: We composed a matrix table with as many rows and columns as A.T.S.J.:
- the first column for entering the serial number of A.T.S.J.;
- 7 columns added to the right, after the last column (of the 7+1 A.T.S.J., specific to the wing and center back positions, and 6+1 A.T.S.J. specific to the pivot position, respectively).

*For wings and center back positions we have 7 A.T.S.J. (*Table 7. 3*) and then we add:*
- Column 8= sum of the + signs.
- Column 9= sum of the - signs.
- Column 10= sum of the „0” signs.
- Column 11= total negative corrections in column 9.
- Column 12= total negative corrections with „0” in column 10.
- Column 13= total negative corrections in columns 11+12.
- Column 14= the utility coefficient.

Table 7. 3. Calculation model for the utility coefficient for the wing, center-back positions (to which there are assigned 7 A.T.S.J.)

*A.T.S.J.								Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections	C.U.
								+	-	0				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1														
2														
3														
4														
5														
6														
7														

**A.T.S.J. = standardized technical actions in the game; C.U.= utility coefficient*
Sign value: + = 0.166; - = - 0.166; 0 = 0.083 (1/6 = 0.166)

*For the pivot position, we have 6 A.T.S.J. (*Table 7. 4*) and then we add:*
- Column 7= sum of the + signs.
- Column 8= sum of the - signs.
- Column 9= sum of the „0” signs.
- Column 10= total negative corrections in column 9.
- Column 11= total negative corrections with „0” in column 10.
- Column 12= total negative corrections in columns 11+12.
- Column 13= the utility coefficient.

Table 7. 4. Calculation model for the utility coefficient for the pivot position (to which 6 A.T.S.J. are assigned)

*A.T.S.J.							Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections	C.U.
							+	-	0				
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
2													
3													
4													
5													
6													

**A.T.S.J. = standardized technical actions in the game; C.U.= utility coefficient*
Sign value: + = 0.2; - = - 0.2; 0 = 0.1 (1/5 = 0.2)

Thus, Table 7. 3 initially has 7 columns (for the wing, center back positions) and as many rows, while Table 7. 4 initially has 6 columns (for the pivot position) and as many rows. In row 1, starting with column 2, the names of the 7 and 6 A.T.S.J. are recorded. The first column will contain, in turn, the numbers of the same 7 and 6 A.T.S.J., respectively, implying that we know exactly which of the A.T.S.J. is encrypted under each of the 7 and 6 numbers, respectively.

Step 3: the assessment of the utility, based on the knowledge of the coach and ours about A.T.S.J., is made successively, namely:

It is assessed, in pairs, successively, to the right (Table 7. 5), the usefulness of one action compared to another (of the 7, respectively 6 A.T.S.J.). This utility is marked with the "+" sign for the action that we consider more useful than its pair, the latter being marked with the „-" sign.

The first action in row 1 does not compare with the one in column 1, that is, with itself, and therefore the space is marked in black.

If we encounter situations when it is difficult to express a categorical preference for one action over another in terms of utility, the two boxes corresponding to the two actions will have the sign "0" (neutral).

In the end we will consider the most useful A.T.S.J. from the point of view of the coach, as a standard coefficient in the calculation of the utility coefficient.

Table 7. 5. The direction for comparing the utility of technical actions in pairs

Direction of the comparison in pairs

A.T.S.J.								Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections
									-	0			
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	■	+	+	+	+	+	+						
2	-	■											
3	-		■										
4	-			■									
5	-				■								
6	-					■							
7	-						■						

Step 4: Different values will be assigned to the utility signs ("+", "-" and "0") for all A.T.S.J., as they are required for the final calculation of the C.U. for each of them. Since we have a number of A.T.S.J. selected for which we calculate C.U. (7 actions, for wing, center back, which determines 6 comparisons for each action, and 6 actions for pivot, which determines 5 comparisons for each action), the value of a sign (comparisons with all the other 6 and 5 goals respectively) plus (+) or minus (-) will be obtained by dividing the maximum possible utility value, 1, by the number of actions taken into account, 6 and 5, respectively, with which the comparisons were made. **Therefore: 1:6= 0.166 (for wing, center-back) and 1:5= 0.2 (pivot).** Thus, each plus sign (+) determines an addition of 0.166 and 0.2 points, respectively, each minus sign (-) determines a decrease of 0.166 and 0.2 points, respectively, and the equal sign between A.T.S.J. ("0") will mean an addition of only half the value, i.e. **0.166:2= 0.083, and 0.2:2= 0.1, respectively,** amount that we subtract from the maximum value of the utility coefficient for each neutral sign („0").

Step 5: adding in the given matrix, in column 8 (for the wing, center back positions) and in column 7 (for the pivot position), the sum of the plus (+) signs, for each A.T.S.J..

Step 6: adding in the given matrix, in column 9 (for the wing, center back positions) and in column 8 (for the pivot position), the sum of the signs with minus (-), for each A.T.S.J.

Step 7: adding in the given matrix, in column 10 (for the wing, center back positions) and in column 9 (for the pivot position), the sum of the signs with zero (0), for each A.T.S.J.

Step 8: multiplying the total negative corrections by minus ("-") in column 9 and 8, respectively, by 0.166 and 0.2, respectively (the score obtained in step 4), for each A.T.S.J. in turn and each is noted in column 11 and 10, respectively.

Step 9: idem step 8, for column 10 and 9, respectively, of the signs with zero ("0"), will be multiplied by 0.083 and 0.1, respectively, each A.T.S.J. in turn and each is written separately in column 12 and 11, respectively.

Step 10: adding in column 13, the signs calculated in columns 11 and 12 (for the wing, center back positions), and in column 12, add the signs calculated in columns 10 and 11 (for the pivot position), for each A.T.S.J..

Step 11: the signs calculated in column 13 and 12 are subtracted for each A.T.S.J. from the maximum coefficient 1 (established in step 3), the rest representing the utility coefficient (C.U.) which is recorded in column 14 (for the wing, center-back positions), and 13 (for the pivot position).

Step 12: The utility coefficient for each item is noted separately: wing (Table 7. 6), center-back (Table 7. 7) and pivot (Table 7. 8), noting that the center and back positions have the same A.T.S.J. standardized.

Table 7. 6. Calculating the utility coefficient for wings

Calculating the utility coefficient WING														
*A.T.S.J.								Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections	C.U.
								+	-	0				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		+	+	+	+	+	+	5	0	1	-	-	-	1
2	-		0	0	+	+	+	3	1	2	-0.166	0.166	0.332	0.67
3	-	0		-	+	+	0	2	2	2	-0.333	0.166	0.499	0.5
4	-	0	+		+	+	+	4	1	1	-0.166	0.083	0.249	0.75
5	-	-	-	-		0	+	1	4	1	-0.644	0.083	0.727	0.27
6	-	-	-	-	0		-	0	5	1	-0.83	0.083	0.913	0.09
7	-	-	0	-	-	+		1	4	1	-0.644	0.083	0.727	0.27

**A.T.S.J. = standardized technical actions in the game; C.U.= utility coefficient*
Sign value: + = 0.166; - = - 0.166; 0 = 0.083 (1/6 = 0.166)

Table 7. 7. Calculating the utility coefficient for center-back

Calculating the utility coefficient CENTRE-BACK														
*A.T.S.J.								Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections	C.U.
								+	-	0				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		+	+	+	+	+	+	5	0	0	-	-	-	1
2	-		-	0	+	+	-	2	3	1	-0.498	0.083	0.581	0.42
3	-	+		+	+	+	0	4	1	1	-0.166	0.083	0.249	0.75
4	-	-	-		0	0	-	0	4	2	-0.664	0.166	0.83	0.17
5	-	-	-	0		0	-	0	4	2	-0.664	0.166	0.83	0.17
6	-	-	-	0	0		-	0	4	2	-0.664	0.166	0.83	0.17
7	-	+	0	+	+	+		4	1	1	-0.166	0.083	0.249	0.75

**A.T.S.J. = standardized technical actions in the game; C.U.= utility coefficient*
Sign value: + = 0.166; - = - 0.166; 0 = 0.083 (1/6 = 0.166)

Table 7. 8. Calculating the utility coefficient for pivot

Calculating the utility coefficient PIVOT													
*A.T.S.J.							Sum of signs			Total negative corrections -	Total negative corrections 0	Total sum of negative corrections	C.U.
							+	-	0				
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1		0	-	+	+	0	2	1	2	-0.2	0.2	0.4	0.6
2	0		-	+	+	0	2	1	2	-0.2	0.2	0.4	0.6
3	+	+		+	+	+	5	0	0	-	-	-	1
4	-	-	-		+	0	1	3	1	-0.6	0.1	0.7	0.3
5	-	-	-	-		0	0	4	1	-0.8	0.1	0.9	0.1
6	0	0	-	0	0		0	0	5	-	0.5	0.5	0.5

**A.T.S.J. = standardized technical actions in the game; C.U.= utility coefficient*
Sign value: + = 0.2; - = - 0.2; 0 = 0.1 (1/5 = 0.2)

Please note that all these values may differ from one team to another, because the values of the utility coefficients are given by each coach depending on the individual potential of the players and the tactical strategy of the match that he/she adopts.

7.10.2.3. The global efficiency coefficient (C.G.E.)

The calculation formula is as follows:

$$C.G.E. = C.S. \times C.U.$$

Where C.G.E.= global efficiency coefficient; C.S.= strain coefficient; C.U.= utility coefficient.

Step 1: we returned to the previously calculated values for C.S. and C.U.

Step 2: for each A.T.S.J. in part (in the case of each of the 12 players included in the research), the C.S. (calculated based on the FC recorded after each action in part, given in relation to the established standard value) with C.U. (established by comparing the pairs between each A.T.S.J. and the rest of the selected A.T.S.J.). The calculations made provide the estimated values of the C.G.E., for each player (Table 7. 9).

Table 7. 9. Cumulative table with the values of the strain coefficient (C.S.), the utility coefficient (C.U.) and the global efficiency coefficient (C.G.E.), for the player in the center position, B.D.

Calculating the coefficients CENTRU- B.D.					
No.	**A.T.S.J.**	**FC**	**C.S.**	**C.U.**	**C.G.E.**
1.	9-meter jump shot (A.S.9m)	169	0.92	1	0.92
2.	6-meter line breakthrough shot (A.P.S.)	174	0.95	0.42	0.4
3.	Position shot after overtake (A.P.D.)	183	1	0.75	0.75
4.	Standing shot (A.P.)	168	0.92	0.17	0.16
5.	7-meter shot (A.7m)	170	0.93	0.17	0.16
6.	Empty net shot (A.P.G.)	163	0.89	0.17	0.15
7.	Second phase shot (A.F2)	180	0.98	0.75	0.74

A.T.S.J.= standardized technical actions in the game; FC = heart rate; C.S. = strain coefficient; C.U. = utility coefficient; C.G.E.= global efficiency coefficient

C.G.E. calculations for the standardized technical actions in the game of handball, on the offensive phase, individually differentiated according to positions, obtained for the other 11 players can be found in Annex 2.

7.10.2.4. The coefficient of standardized positive actions in the game (C.Ap.S.J.)

Following the calculations made for C.Ap.S.J. and presented in Table 7. 10, we identified a maximum value of importance (1) for Ap.S.J.5, corresponding to the action of obtaining a shot from 7 meters simultaneously with provoking a suspension of 2 minutes. The lowest value of C.Ap.S.J. was obtained by Ap.S.J.8 (technical foul).

Table 7. 10. The results of the calculations for the coefficient of standardized positive actions in the game

No.	Ap.S.J.	C.Ap.S.J.
1.	Assist (P.D.)	0.848
2.	Regaining ball possession after goal save (R.M.)	0.506
3.	7 meter obtained (7M O.)	0.658
4.	2 min. obtained (2M O.)	0.886
5.	7m + 2 min. (7M+2')	1
6.	Lane formation (F.C.)	0.506
7.	Successful defensive wall (P.R.)	0.430
8.	Technical foul (F.T.)	0.164
9.	Shot blocking (B.A.)	0.316
10.	Lane close off (Î.C.)	0.392
11.	Interception (I)	0.544
12.	Steal (D)	0.354
13.	Ball intercepted/regained on the court (M.R.t)	0.202
14.	Efficient turnover (R.E.)	0.278

The complete matrix table and the registration form of the Ap.S.J., specific to all the players of the CSM Galați team, are included in the Annex section (Annex 3).

7.10.2.5. The standardized error coefficient in the game (C.G.S.J.)

According to Table 7. 11, which includes the results of the calculations performed for C.G.S.J., we have identified a maximum value of utility (1) for G.S.J.10, corresponding to the mistake of obtaining the red card, which entails the disqualification of the player from the match. The slightest mistake was 0.088 in the case of C.G.S.J.13 (unrecovered ball).

Table 7. 11. The results of the calculations for the standardized error coefficient in the game

No.	G.S.J.	C.G.S.J.
1.	Missed pass	0.430
2.	Dropped ball	0.164
3.	Double dribble	0.506
4.	Offensive foul	0.544
5.	Steps	0.430
6.	No marking (inclusively on turnover)	0.316

7.	Foot	0.316
8.	Lack of lane close off	0.696
9.	2 min. suspension	0.924
10.	Red card	1
11.	7 m provoked	0.810
12.	Wrong switch	0.430
13.	Ball not intercepted/failure to regain the ball	0.088
14.	6-meter line	0.430

The registration form for G.S.J. specific to all the players of the CSM Galați team is included in the Annex section (Annex 4).

7.10.2.6. Elaboration of the formula for the overall efficiency coefficient in the game (C.E.T.J.)

This formula includes both the global efficiency coefficient (which refers to the level of efficiency of the players in the attack phase, depending on the goals scored and misses), and the difference between the standardized positive action coefficient and the standardized error coefficient, all related to the playing time available to the sportswoman.

The calculation formula we devised is as follows:

$$\boldsymbol{C.E.T.J.} = \frac{\boldsymbol{C.G.E.} + (\boldsymbol{C.Ap.S.J.} - \boldsymbol{C.G.S.J.})}{\boldsymbol{T.J.}}$$

Where:
C.E.T.J.= the overall efficiency coefficient in the game;
C.G.E.= global efficiency coefficient $(C.S. \times C.U.)$ *of all A.T.S.J. in the match:*
C.S.= the strain coefficient of the A.T.S.J.;
C.U.= the utility coefficient A.T.S.J;
C.Ap.S.J.= the coefficient of standardized positive actions in the game;
C.G.S.J.= the standardized error coefficient in the game;
T.J.= playing time.

The model of the cumulative table of the coefficients required for the calculation of the above formula is represented in Table 7. 12.

Table 7. 12. Cumulative table model of the coefficients required to calculate the overall in-game efficiency coefficient

Subjects	COEFFICIENT VALUES			
	C.G.E.	C.Ap.J.	C.G.J.	C.E.T.J.
Subject 1				
Subject 2				
...				
AVERAGE				

The main objective of this stage in our research was *to modify the formula for calculating efficiency proposed by Alexe, N., by incorporating the physiological heart rate index and the coefficients calculated for positive actions and standardized errors in the game and then reporting these calculations to the total game time.* In this way, the calculation formula for C.E.T.J. can be a *personalized instrument for objective assessment, regardless of age, gender or level of play.*

7.11. Equipment and materials required for preliminary research

The specialized equipment used in the evaluations through tests outside the match or on the court was both that available in the Human Performance Research Center, within the Doctoral School for Sport Science and Physical Education, Galați University, and the equipment purchased from own funds.

7.11.1. The PUSH Band device

PUSH 2.0 (Strength Inc., Toronto, Canada) is a revolutionary micro technological device (Figure 7. 6), which has the following physical dimensions: height, 77.5 mm, width, 53.3 mm, depth, 15 mm and weight, 32 g. It allows wireless measurement and reporting of data, over a range of 9 meters, thanks to the chip Integrated Bluetooth 5.0. The device also has a built-in triaxial accelerometer and gyroscope, which each have a data recording frequency of 1000 Hz and there is also the possibility of merging the two sensors to produce a 200 Hz signal.[8] The accelerometer determines the linear acceleration and the gyroscope detects changes in body position relative to a reference point.

In our research, we used the PUSH band as a tool to evaluate all jump and medicine ball throw tests.

Figure 7. 6. The PUSH 2.0 device, photo source www.trainwithpush.com

7.11.1.1. PUSH 2.0 device portability

The technology behind PUSH 2.0 allows multiple and even simultaneous testing of athletes in a relatively short amount of time. Thus, it can be worn in Body Mode or Bar Mode, depending on the objectives of the research. How to wear the device is presented in Figure 7. 7. When worn on the forearm, the sensor is inserted into the pocket of an elastic band with adhesive; when worn on the waist, it is inserted in an adjustable strap.

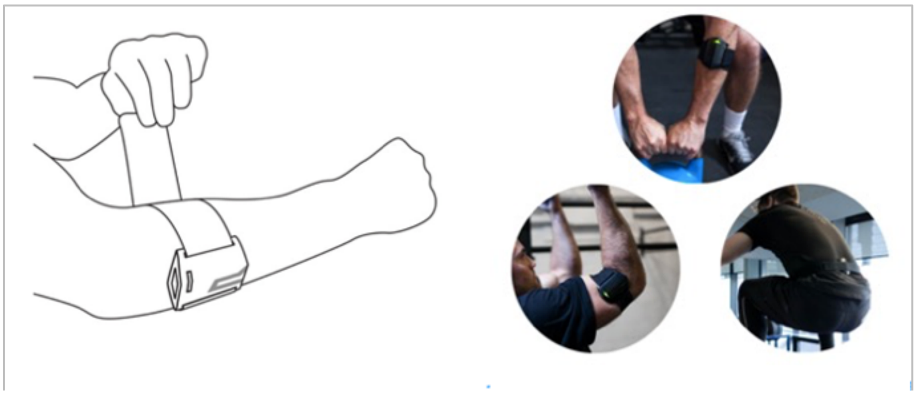


Figure 7. 7. Ways to wear PUSH 2.0 band correctly, according to the manufacturer

Once turned on, the device can be connected via Bluetooth to the PUSH Pro-Athletic Training Tracker application, compatible with smartphones or tablets, which have Android or iOS. Another possibility to connect is directly on the laptop, by accessing the dedicated portal on the manufacturer's page[9].

[8] Rami Alhamad, "Technical Specifications". Available at: https://intercom.help/pushcenter/en/articles/741110-technical-specifications [Accessed on 15.09.2020].
[9] https://app.pushstrength.com/dashboard

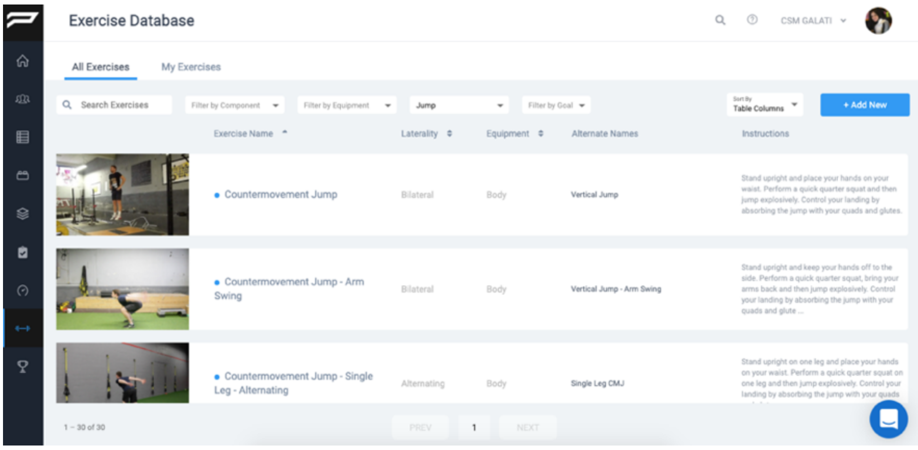


Figure 7. 8. The Push portal, where all applied test results are stored (screenshot from the account used by the authors)

Regardless of the device used for data sharing, it is necessary to create a personal account, where the results of all tested athletes can be stored (Figure 7. 8) but the data can also be provided in real time (Figure 7. 9).

Figure 7. 9. Sample data provided by PUSH in real time (screenshot from the account used by the authors)

The accuracy and reliability of the sensors integrated in this modern inertial measurement unit have been verified in studies comparing the results obtained by PUSH 2.0 with those collected by the instruments considered as reference or "gold standards" in monitoring sports performance, such as strength platforms, contact mats or inductive linear position sensors. These validation studies followed and evaluated the process of estimating the parameters of the vertical jump, CMJ (Lake et al., 2018; McMaster et al., 2020) and squat jump, SJ (Orser et al., 2020).

PUSH 2.0 can determine the values of parameters associated with physical on-court tests, which assess the ability of aerobic (running) or anaerobic effort (jumping, throwing, lifting weights).

7.11.2. The Garmin Fenix 5S smart watch (GF5S)

The Garmin Fenix 5S watch (Garmin Ltd, Olathe, KS) is a modern portable device (Figure 7. 10), with dimensions of 47 x 47 x 15.5 mm. It uses a multisensory monitor based on Elevate ™ technology, which involves measuring heart rate directly from the wrist using an optical sensor, without the user having to use a heart belt. In addition, the integrated Global Positioning Sensor (GPS) allows you to determine distances, speed, cadence or running pace outside, and inside, these indicators can be monitored based on the integrated accelerometer.

This research tool was used in the preliminary experiment at different times, as follows:

- during the 30-15 IFT test;
- in the friendly matches in the company of the Gloria Buzău team;
- in our interventions for the physiological evaluation, according to the implementation of the passive recovery protocol;
- in our on-court assessment interventions, on the court, to determine the total distances covered and the movement speed.

Figure 7. 10. The Garmin Fenix 5S watch, photo source www.buy.garmin.com

To monitor performance, the Garmin Connect™ application must be installed on a laptop or phone and an account created. This way, all physical activity can be recorded, analyzed, shared, and even exported to Excel files, for example, for further analysis.

The pairing of the device with the phone is done with the help of wireless technology through the Bluetooth function, while the data regarding the activity carried out can be transmitted to the Garmin Connect account, immediately after the end of the activity.

Each watch distributed to the players included in this research was registered on the individual athlete's sheet, thus having a clear record of individual physical activity, which was then downloaded to the special account we created on Garmin Connect.

7.11.3. Accutrend Plus

For the collection of capillary blood samples, the Accutrend Plus instrument is used in conjunction with test strips for the selected parameter (which come with special codes) and a puncture device. In our research we used the VivaChek Eco puncture device (Figure 7. 11).

To perform a test (Figure 7. 11), the instrument must be placed on a straight surface, followed by the dedicated button. The waiting time for results is 60 seconds for lactic acid, 12 seconds for glucose, cholesterol 180 seconds and triglycerides max. 174 seconds

Figure 7. 11. The test kit used in our research

Despite the tendency to overestimate glucose and triglyceride levels, *Accutrend Plus is considered a viable alternative to laboratory testing (Coqueiro et al., 2014),* with results from capillary blood sampling providing fast and accurate information similar to those from arterial blood in medical testing centers (Seoane et al., 2013).

This instrument was used at three different times during the physiological evaluation, before any effort (in the players' locker room), after the standard match warm-up (T1 PP) and after the implementation of the 15-minute passive recovery protocol (T2 PP).

7.11.4. The Veroval thermometer

The model used in our research is Veroval DS 22 (Figure 7.12), which gave us the advantage of a quick measurement of body temperature from the forehead using infrared technology. The measuring sensor detects the emitted infrared radiation and returns the measurement result within one second. The body temperature measurement range, in the forehead mode, is between 34°C - 43°C, with a measurement accuracy of ± 0.3°C in the range of 35°C - 42°C, the waiting time between measurements of at least 5 seconds and it can store values of up to 10 subjects.

Figure 7. 12. The Veroval thermometer, photo source, www.helpnet.ro

This instrument was used at three different times during the physiological evaluation, before any effort (in the players' locker room), after the standard match warm-up (T1 PP) and after the implementation of the 15-minute passive recovery protocol (T2 PP).

7.11.5. The IMDK C101A2 pulse oximeter

To estimate the level of oxygen in the peripheral blood, we used the IMDK finger pulse oximeter, model C101A2, version V1.1, released in April, 2020 (Figure 7. 13). The measurement of this parameter will give us indications about the state of fatigue of the athletes in the different moments of testing, organized within our research.

Figure 7. 13. The IMDK pulse oximeter and the OLED screen, photo source https://www.educlass.ro/articole-sanatate/imdk/pulsoximetru-pentru-deget-certificat-medical/?img=309649

The reason why the pulse oximeter is used on the finger is because in this area the skin has a higher vascular density compared to the chest area, for example (Mannheimer, 2007).

This instrument was used in three different moments of the physiological evaluation, before any effort (in the players' locker room, TV), after the standard match warm-up (T1 PP) and after the implementation of the passive recovery protocol, lasting 15 minutes (T2 PP).

7.11.6. DJI Osmo Pocket

DJI Osmo Pocket (Figure 7. 14) is an innovative portable photo-video device that has a 3-axis gimbal offering the possibility of filming in very good mobility and stability conditions. Because the game of handball is one of the most dynamic team sports, which includes many actions carried out at a sustained pace, this device allowed the filming of matches organized in our research at a higher quality. The recordings obtained were stored on a memory card and subsequently downloaded to the personal laptop, in order to analyze the players' court performance.

The dimensions of the device are 121.9 × 36.9 × 28.6 mm, the camera has a 1/2.3" CMOS sensor, and filming is done in 4K at 60 frames per second.

Figure 7. 14. Photo-video recording device, DJI Osmo Poket, photo source, https://store.dji.com/product/osmo-pocket?vid=48141

This video device was used in the preliminary experimental research for the recording of friendly matches in the company of the Gloria Buzău team and for the recording of the 6 training game sessions, organized during our intervention for the purpose of motor and technical-tactical evaluation, on the court.

CHAPTER 8. THE ORGANIZATION OF THE PRELIMINARY EXPERIMENTAL RESEARCH ACTIVITY

8.1. Sample group, location and details concerning the organization of the preliminary research

The preliminary research included a number of 12 players, members of the CSM Galați women's handball team, who during the preliminary experiment activated in Division A of the Romanian women's handball championship, succeeding at the end of the 2019-2020 edition to be promoted to the National League. Only on court players were included in the study, two for each position (left wing, right wing, left back, right back, center and pivot), goalkeepers being excluded due to the different effort demands and technical-tactical involvement, specific to the position. Collectively, the average age is 31.9 ± 4.05 years, the average weight is 66.1 ± 5.8 kg, the average height is 173 ± 3.8 cm and the body mass index is of 2.2 ± 0.2.

The locations for the preliminary research were at the Sala Sporturilor (Sports Hall) on Stadionului Street, no. 1-7, 2-8 and at the Siderurgistul Sports Hall with the address at 2 Cloșca Street.

8.2. Stages and strategies specific to the preliminary research

Stage I (October 2018-October 2019) was scheduled to address the specialized literature.

Stage II: between August 2019 and September 2019 we structured and elaborated the plan for conducting the preliminary research.

Stage III: October 2019 - March 2020, the evolution of the CSM Galați team players was recorded, as part of the national competition in Division A, the 2019-2020 edition, from a technical-tactical point of view. The same period was scheduled for the elaboration and transmission to 24 coaches and specialists in the field of performance sports of an opinion questionnaire that included 22 questions focused on the topic addressed in our research.

Stage IV: March-June 2020 - quarantine period, dedicated to the bibliographic study and the elaboration of new research directions adapted to the pandemic period. Also during this period, we analyzed and interpreted statistically the questionnaire applied to specialists in the field.

Stage V: July-September 2020 (preparatory period of the first macrocycle) - we recorded the results obtained by the players in the on-court tests to learn the maximum aerobic capacity. We carried out the physical and physiological evaluations and we worked on the elaboration of the calculation formula for the overall efficiency coefficient in the game, which would allow us an objective technical-tactical evaluation.

Stage VI: October-November 2020- we applied the motor and technical-tactical evaluation of the players, by organizing the bilateral training games, in conditions of passive recovery;

Stage VII: November 2020 - statistical analysis and interpretation of the results obtained by the player in the evaluations applied in conditions of passive recovery.

8.3. General strategy for the implementation of evaluation protocols, in the framework of the preliminary experimental research, under conditions of passive recovery

The purpose of the evaluations carried out in the preliminary experimental research was to identify the values of the physical and physiological indices reached after the warm-up for the match and then to identify the changes caused by 15 minutes of inactivity (passive recovery) on these indices. In addition, we wanted to know the level of motor and technical-tactical performance of the players, in the conditions of entering the court after 15 minutes of passive recovery, from the substitute position. Therefore, three different evaluations were organized (physical, physiological and on-court), with their own structure, duration, methods and means of testing.

The scheduling and planning of the evaluation days within the preliminary research was done both according to the structure of the 2020-2021 competition season and the weekly training program of the team, established by the coach.

The steps taken to apply the three types of assessment are presented in Figure 8.1.

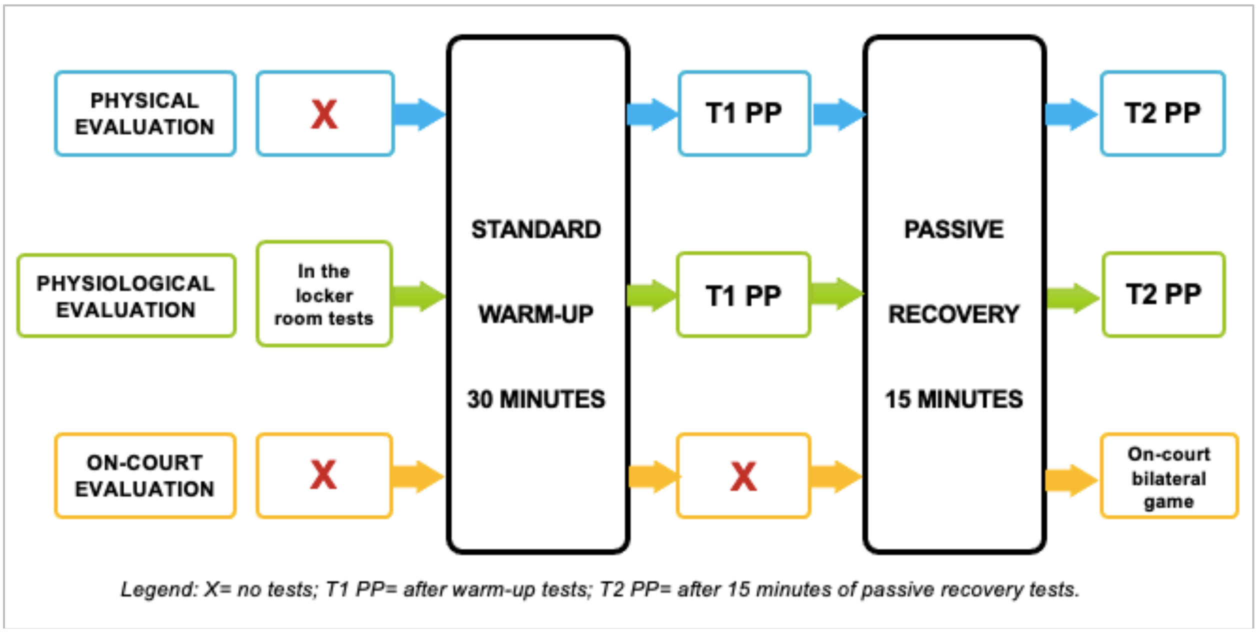


Figure 8. 1. The steps taken for the evaluations made in the preliminary research, with the implementation of the passive recovery

According to the schematic representation in Figure 8. 1, during the physiological evaluation we performed a number of 3 tests (in the locker room, after warm-up and after the passive recovery), in the case of the physical evaluation the players were tested twice (after warm-up and after the passive recovery) and in the case of on-court testing, only one test was performed after the passive recovery.

8.3.1. Joint organizing activities, within the frame of the evaluation protocols

8.3.1.1. The standard warm-up of the CSM Galați team

This training program for effort represents the standard warm-up for the match, specific to the team and it lasts 30 minutes. In order not to influence the results of the evaluation tests, we asked the team coach to keep the same warm up structure throughout the research.

General warm-up consists of individual or collective exercises, without the ball, mainly under the guidance of the team's physical trainer.

The *specific warm-up* is the one adapted with the ball, which involves the repeated performance of the main elements, procedures and technical-tactical actions, specific to the game of handball.

8.3.1.2. Passive recovery implemented between tests in evaluation protocols

The **passive recovery** represents the period of **complete inactivity** that all the substitute players go through, regardless of the reason why the athletes are in this position (coach's preferences, injury, low performance, etc.). During the handball matches, the passive recovery involves a seated position on the benches or on the chairs specially placed on the edge of the court. At the moment, passive recovery (sitting on the bench) is imposed by the Rules for the organization and staging of competitions, according to the International Handball Federation (IHF, 2016).

In our preliminary research, the players were instructed to sit on the bench and remain completely inactive after performing the initial tests, immediately after warm up (T1 PP), as would happen in an official match, in a seated position for 15 minutes until they are called for the final test, T2 PP (Figure 8. 2).

Figure 8. 2. Example of passive recovery applied to players included in the preliminary search (Group 1 on the left of the image, Group 2 on the right of the image)

8.3.2. Planning and organizing the physical evaluation protocol, under conditions of passive recovery

The 12 players included in the research were subjected to a number of **7 physical tests** focused on assessing the combined qualities of strength-speed and determining the capacity of anaerobic effort. All the tests performed during the physical evaluation took place during the preparatory period of the first macrocycle of the 2020-2021 competition season, for a period of two weeks, from September, on Tuesdays, Thursdays and Saturdays, in the same time interval, according to the training program detailed in Table 8. 1. Before starting the physical assessment, we set aside the last week of August to *familiarize* the players with the tests and measuring instruments needed for the preliminary experiment.

The team was divided into two groups of 6 players each (group 1 and group 2), in pairs on the playing positions, the formula being kept throughout the preliminary experiment.

Table 8. 1. Locating our interventions through physical evaluation, in the weekly training cycle

SEPTEMBER 2020- TRAINING PERIOD PHYSICAL EVALUATION				
Date	**Day**	**Time slot**	**Group**	**Tests conducted**
1 September	Tuesday	9:00-10:30	Group 1	CMJ AF / CMJ AS
2 September	Wednesday	9:00-11:00	-	-
3 September	Thursday	15:30-17:00	Group 1	SJ / RSI 10/5
4 September	Friday	9:00-10:30	-	-
5 September	Saturday	11:30-13:30	Group 1	AMMD / AMMD / TA 10 m
6 September	Sunday	Free	-	-
7 September	Monday	15:30-17:30	-	-
8 September	Tuesday	9:00-10:30	Group 2	CMJ AF / CMJ AS
9 September	Wednesday	9:00-11:00	-	-
10 September	Thursday	15:30-17:00	Group 2	SJ / RSI 10/5
11 September	Friday	9:00-10:30	-	-
12 September	Saturday	11:30-13:30	Group 2	AMMD / AMMD / TA 10 m
13 September	Sunday	Free	-	-

CMJ AF= countermovement jump with arms fixed; CMJ AS= countermovement jump with arm swing; SJ= squat jump' RSI 10/5= reactive strength index; AMMD= medicine-ball right side throw; AMMS= medicine-ball left side throw; TA 10 m= 10-meter acceleration test

We opted for this strategy because, given that the warm-up ends simultaneously, the time required for the evaluation would have resulted in a too long waiting period and would have certainly influenced the results of some players tested towards the end.

The first stage of the physical evaluation involved going through the standard warm-up for the match, of the whole team, under the close supervision of the head coach who was asked to make sure that the players responded responsibly to the required efforts. At the end of the first warm-up stage, the players were called for testing, on the edge of the court, depending on the group they belonged to (1 or 2). The other 6 players continued training according to the schedule. On Tuesday and Thursday, the jump tests were performed, and on Saturday, the medicine ball throwing tests and the 10-meter acceleration test.

For all the jumping and medicine ball throwing tests we used the portable device PUSH, version 2.0, which allowed the multiple testing of the players.

In the case of jump tests, the measuring instrument was inserted into an adjustable strap at the belt of the tested athlete, and in the case of throws, the device was inserted into the pocket of the adhesive tape provided and attached to the athlete's forearm. The positioning of the sensor was followed by the connection of the device, through the Bluetooth function, to the laptop and the smartphone used in the research. After the first test (T1 PP), each player took a seat on the bench and remained inactive for 15 minutes, after which she was called back to the rehearsal area for the second test (T2 PP).

The parameters measured by means of the jump tests were:

- JH= jump height, which was derived from the flight time, by applying the equation 9.81 X flight time ^{2}/8;
- FT= flight time;
- GCT= ground contact time;
- RSI 1= reactive strength index: the JH/GCT ratio;
- PP= peak power;
- PV= peak velocity.

Each jump was performed 3 times, noting the best values of the parameters provided by the PUSH application.

The parameters measured by this medicine ball side throwing test were:

- AP= average power;
- PP= peak power;
- AV= average velocity;
- PV= peak velocity.

As in the case of jumping, the medicine ball side throw was also performed 3 times on each side, recording the best values obtained for each parameter.

For *the evaluation of the 10-meter acceleration speed*, we used the **stopwatch**, although nowadays the photoelectric cells are used.

As noticeable in Table 8. 2, in the case of the physical assessment, the tests were performed at two different times: the initial test, immediately after the match warm-up, before the passive recovery (T1 PP) and the final test, immediately after the passive recovery period (T2 PP). In this case, it was decided to exclude the tests before the match warm-up, because we wanted to avoid the risk of injury due to the lack of preparation of the body for effort.

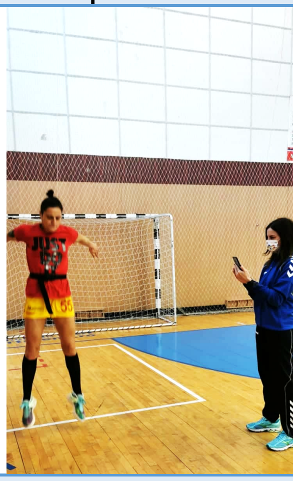
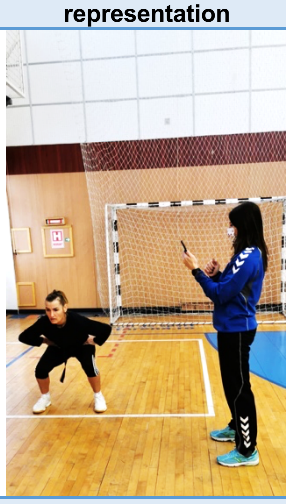
Table 8. 2. Physical assessment model

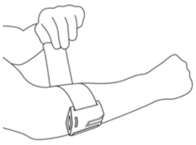
30' COLLECTIVE WARM UP
⬇
T1 PP- after warm-up (according to group schedule) CMJ AF, CMJ AS, SJ, RSI 10/5, AMMD/AMMS, TA 10 m
⬇
15' PASSIVE RECOVERY 
⬇
T2 PP- after 15' of passive recovery (according to group schedule and tests) CMJ AF, CMJ AS, SJ, RSI 10/5, AMMD/AMMS, TA 10 m

After the standard match warm-up, according to the plan made for each of the two groups, the players were called, in turn, to the area intended for the test protocol. The test time required for each player was very short, up to a minute. In order not to lose the effects of the warm-up, the players who were waiting to be tested were trained to perform some dynamic stretching exercises.

The jumping and medicine ball throwing tests, included in the physical evaluation are described in Table 8. 3.

Table 8. 3. Description of the jumping and medicine-ball throwing tests

<table>
<tr><th>Movement type / Device positioning</th><th>Test</th><th>Technical description</th><th>Observations</th><th>Photographic representation</th></tr>
<tr><td rowspan="7">Jump
</td><td>The countermovement jump (CMJ AF)</td><td>- from a standing position, feet shoulder width apart, arms bent, hands on hips, a semi-squat is quickly performed, followed by 3 explosive vertical jumps, as high and as fast as possible.
- The test aims to evaluate the elastic explosive strength at the level of the lower limbs.</td><td>- landing on two feet will be cushioned by the shock absorption with the help of the quadriceps femoris and gluteus muscles; the best result of the 3 is recorded.</td><td></td></tr>
<tr><td>Test</td><td>Technical description</td><td>Observations</td><td>Photographic representation</td></tr>
<tr><td><u>CMJ with arm swing (CMJ AS)</u></td><td>- from a standing position, feet shoulder width apart, arms straight and parallel to the body, a semi-squat is quickly performed simultaneously with the arms swinging backwards, after which 3 explosive vertical jumps are performed, as high and as fast as possible.</td><td>- landing on two feet will be cushioned by the shock absorption with the help of the quadriceps femoris and gluteus muscles; the best result of the 3 is recorded.</td><td></td></tr>
<tr><td>Test</td><td>Technical description</td><td>Observations</td><td>Photographic representation</td></tr>
<tr><td><u>The Squat Jump-SJ</u></td><td>- from a semi-squat position arms bent, hands on hips, an explosive vertical jump and a landing in the initial position. The jump is executed 3 times with a short break between repeats.
- The test aims to evaluate the explosive strength at the level of the lower limbs.</td><td>- landing on two feet will be cushioned by the shock absorption with the help of the quadriceps femoris and gluteus muscles; the best result of the 3 is recorded.</td><td></td></tr>
<tr><td>Test</td><td>Technical description</td><td>Observations</td><td>Photographic representation</td></tr>
</table>

	RSI (Reactive Strength Index) 10/5 (Stiffness) RSI 10/5	- from a standing position, arms bent, hands on hips, 10 explosive vertical jumps are executed, as high and as quick as possible. - The test measures the explosive strength of the legs by executing 10 dynamic jumps.	- **landing on two feet** will be cushioned by the shock absorption with the help of the quadriceps femoris and gluteus muscles; RSI is the ratio between the average of the best 5 jumps between the height index (JH) and the ground contact time (GCT).	
	Test	**Technical description**	**Observations**	**Photographic representation**
Throw	Medicine ball wall toss (to the right) AMMD	- from a standing position, perpendicular to the wall, right shoulder facing forwards, the medicine ball held with both hands, explosive turn of the trunk and throw against the wall. - The test aims to evaluate the explosive strength of the medicine ball side throw with both hands	- the test is performed with a medicine ball of 3 kg; the test is conducted 3 times and the best result is recorded.	
	**Test**	**Technical description**	**Observations**	**Photographic representation**
	Medicine ball wall toss (to the left) AMMS	- from a standing position, perpendicular to the wall, left shoulder facing forwards, the medicine ball held with both hands, explosive turn of the trunk and throw against the wall. The test aims to evaluate the explosive strength of the medicine ball side throw with both hands	- the test is performed with a medicine ball of 3 kg; the test is conducted 3 times and the best result is recorded.	

8.3.3. Planning and organizing the physiological evaluation protocol, under conditions of passive recovery

The physiological evaluation included a number of **5 investigations**, which aimed to identify the basic values and change them in three different moments: after the match warm-up and after the implementation of the 15-minute passive recovery. The equipment used was diverse and adapted according to the measured indices.

Thus, for the investigation of the **heart rate (FC)**, we used the smart watches of the Garmin Fenix 5S brand. The **temperature** was recorded with the Veroval infrared thermometer. **Biochemical parameters** (lactic acid and serum glucose) were measured using the Accutrend Plus device. Blood **oxygen saturation** was measured using a pulse oximeter.

According to Table 8. 4, the players were tested on 15 and 22 September 2020 (Tuesday). Three days before the actual experiment, we held a session to *familiarize* the players with the methodology used and at the same time the players were instructed that in the morning of the tests*, they should not eat or drink coffee, but only water.*

Table 8. 4. Locating our interventions through physiological evaluation, in the weekly training cycle

SEPTEMBER 2020- TRAINING PERIOD				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
15 September	Tuesday	9:00-10:30	Group 1	FC / Tc / AL / G / SpO_2
22 September	Tuesday	9:00-10:30	Group 2	FC / Tc / AL / G / SpO_2

FC= heart rate; TC= body temperature; AL= lactic acid; G= serum glucose; SpO_2= oxygen saturation in the blood.

Because it is recommended that lactic acid be harvested 3 minutes after the end of exercise, during this time we recorded the values of FC, Tc and SpO_2. For the analysis of the two biochemical indices (AL and G) we decided to collect the blood sample required for AL first because the analysis time of the Accutrend Plus device for this index is 60 seconds, an interval that allowed us to collect the second blood sample, necessary for serum glucose, this parameter being analyzed in just 12 seconds. All data was noted on individual sheets and then we created databases in Microsoft Excel for further analysis.

Table 8. 5. Physiological evaluation model

Locker room testing (according to group schedule)
FC / Tc / AL / G / SpO_2

↓

30' COLLECTIVE WARM-UP

↓

T1 PP- after warm-up (according to group schedule)
FC / Tc / AL / G / SpO_2

↓

15' PASSIVE RECOVERY

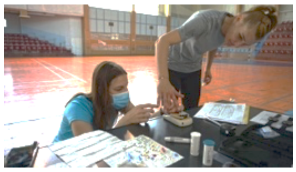
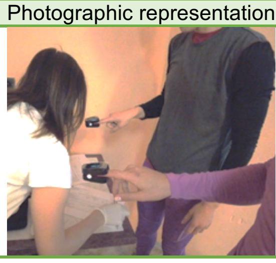
↓

T2 PP- after 15' of passive recovery (according to group schedule)
FC / Tc / AL / G / SpO_2

The evaluation model is presented schematically in Table 8. 5. In the case of the physiological evaluation, in addition to T1 PP and T2 PP, we wanted to perform an additional test, before any physical effort, in the players' locker room, in order to learn the basic values of all physiological indices chosen for investigation, for further analysis.

The instruments used for each physiological test are presented in Table 8. 6.

Table 8. 6. Presentation of physiological investigation tools

Measured physiological index	Measuring device	Measurement time	Photographic representation	Observations
1. Heart rate (FC)	Garmin Fenix 5S 	instantly		- The FC value is displayed on the clock screen, being measured every 5 seconds.
Test	Measuring device		Photographic representation	Observations
2. Body temperature(Tc)	Veroval thermometer 	5 seconds		- For accurate measurement, the players' foreheads had to be dry.
Test	Measuring device		Photographic representation	Observations
3. Lactic acid (AL)	Accutrend Plus 	60 seconds		- In the T1 PP and T2 PP tests, the sample was taken 3 minutes after the end of the effort.
Test	Measuring device		Photographic representation	Observations
4. Serum glucose (G)	Accutrend Plus 	12 seconds		- Blood samples for this parameter were collected from the same insertion for AL. However, there were cases when an additional puncture was needed due to insufficient blood.
Test	Measuring device		Photographic representation	Observations
5. Oxygen saturation (SpO_2)	Pulse oximeter 	5 seconds		- It is used on the finger because in this area the skin has a higher vascular density compared to the chest area.

8.3.4. Planning and organizing the on-court evaluation protocol, under conditions of passive recovery

The evaluation of the players on the court presupposed recording the motor performance and the technical-tactical efficiency, during six sessions of bilateral friendly play between the two groups formed at the beginning of the preliminary experiment, with a fixed duration of 15 minutes, organized on different days. The *motor evaluation* involved recording the total distance covered and the speed of movement, values recorded with the help of Garmin Fenix 5S watches, which were distributed to the players before the start of the match warm-up. All watch data was stored in the account created on the Garmin Connect application, installed on the laptop used in the research. The technical-tactical efficiency was quantified with the help of the *overall efficiency coefficient in the game* (C.E.T.J.), calculated with the help of the formula developed by us, following the replay of the 6 matches and the collection of all necessary quantitative indicators. The 6 bilateral matches were organized and planned together with the team coach, during the competition period of the first macrocycle of the 2020-2021 competition season, for a period of two months (October and November), only on Saturdays, as can be seen in Table 8. 7.

Table 8. 7. Planning the 6 bilateral matches, organized for motor and technical-tactical evaluation, on the court

OCTOBER 2020- COMPETITION PERIOD				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
3 October	Saturday	9:00-10:30	Both groups	**Match 1** Distance / Speed/C.E.T.J.
17 October	Saturday	15:30-17:00	Both groups	**Match 2** Distance / Speed/C.E.T.J.
31 October	Saturday	11:30-13:30	Both groups	**Match 3** Distance / Speed/C.E.T.J.
NOVEMBER 2021- COMPETITION PERIOD				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
7 November	Saturday	9:00-10:30	Both groups	**Match 4** Distance / Speed/C.E.T.J.
21 November	Saturday	15:30-17:00	Both groups	**Match 5** Distance / Speed/C.E.T.J.
28 November	Saturday	11:30-13:30	Both groups	**Match 6** Distance / Speed/C.E.T.J.

C.E.T.J.= the overall efficiency coefficient in the game.

The stages covered by the players on the days of the on-court evaluation are represented schematically in Table 8. 8.

Table 8. 8. On-court evaluation model in preliminary research

30' TEAM WARM-UP

↓

15' PASSIVE RECOVERY

↓

T2 PP- after 15' of passive recovery
Bilateral game - Distance, speed, C.E.T.J.

CHAPTER 9. THE RESULTS OF THE PRELIMINARY EXPERIMENTAL RESEARCH

9.1. The interpretation of the data collected following the application of the social survey method

24 coaches were interviewed, with an experience of between 10 and 30 years in the field. The 22 proposed questions were structured in 5 sections and the opinion of the coaches was requested on:

1. Women's handball in Romania (HFR).
2. The evolution of players in matches (EJM).
3. Passive recovery (PP).
4. Active recovery (PA).
5. Match strategy of Romanian coaches (SMAR).

Construct 1 (C1): **The effects of the passive recovery, on the edge of the court, during the matches, in the opinion of the Romanian coaches**

Evaluating this construct, we obtained an average score of 3.72. This shows that the **Romanian coaches are somewhat in agreement with the effects of the passive recovery, but they are not entirely convinced that these effects exist (**Figure 9. 1**).**

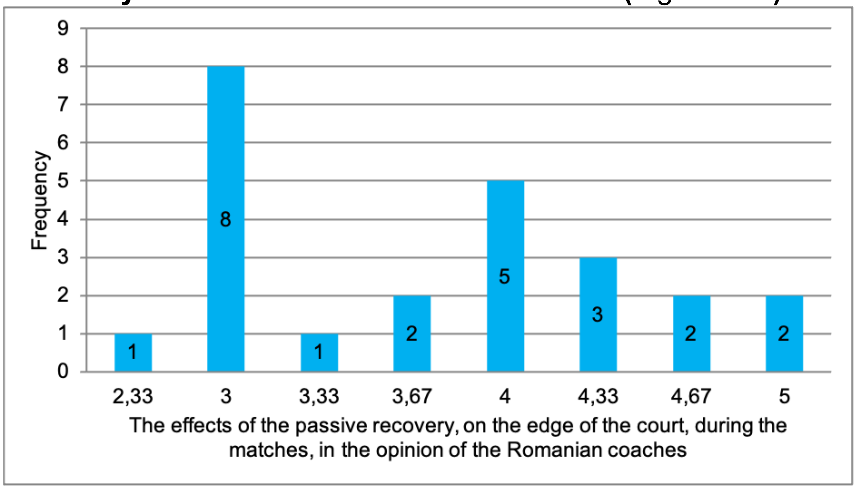


Figure 9. 1. Graphic representation C1

Construct 2 (C2): The appropriateness of using active recovery in the opinion of the Romanian coaches

On a scale of 1 to 5, where 1 means that the coaches do not agree at all with the appropriateness to use the active recovery, and 5 means that they largely agree with its appropriateness, we obtained an average score of 4 (Figure 9. 2), thus demonstrating that the **Romanian coaches consider, to a large extent, opportune the use of the active recovery.**

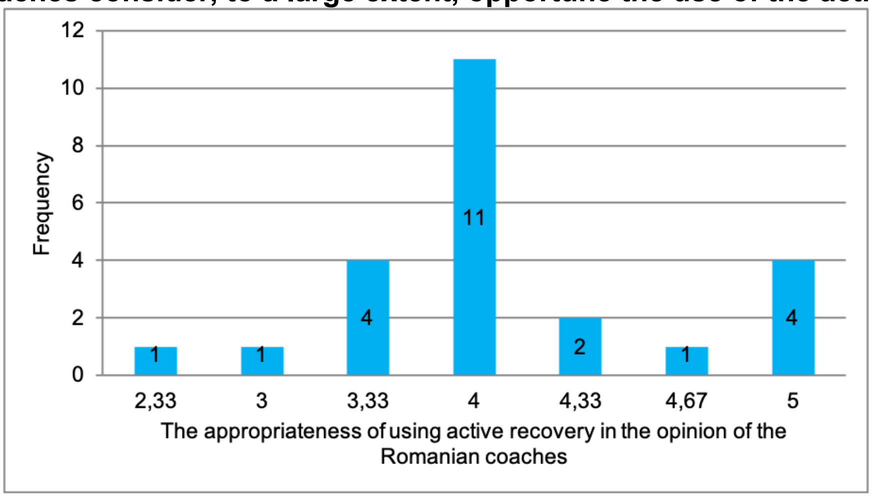


Figure 9. 2. Graphic representation C2

The relationship between the appropriateness of using the active recovery in the opinion of Romanian coaches (C2) and the actual use of the active recovery (PA4)

Although in the opinion of the Romanian coaches the use of the active recovery is appropriate to a large extent, the existence of this fact is not accompanied by an application, to the same degree, of the active recovery programs (Figure 9. 3).

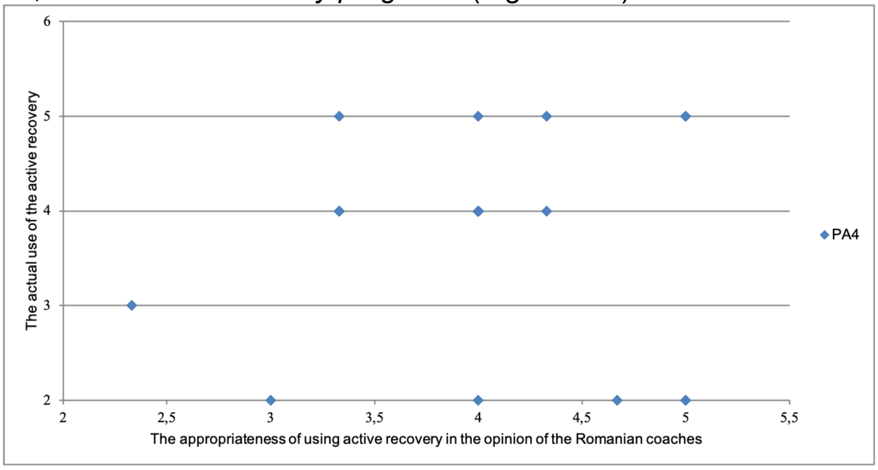


Figure 9. 3. The relationship between the appropriateness of using active recovery in the opinion of Romanian coaches and the actual use of the active recovery

The relationship between the effects of the passive recovery (C1) and the appropriateness of using active recovery (C2)

As noticeable in Figure 9. 4, *the more the coaches believe in the effects of the passive recovery on the substitute players, the more they consider appropriate the use of active recovery.*

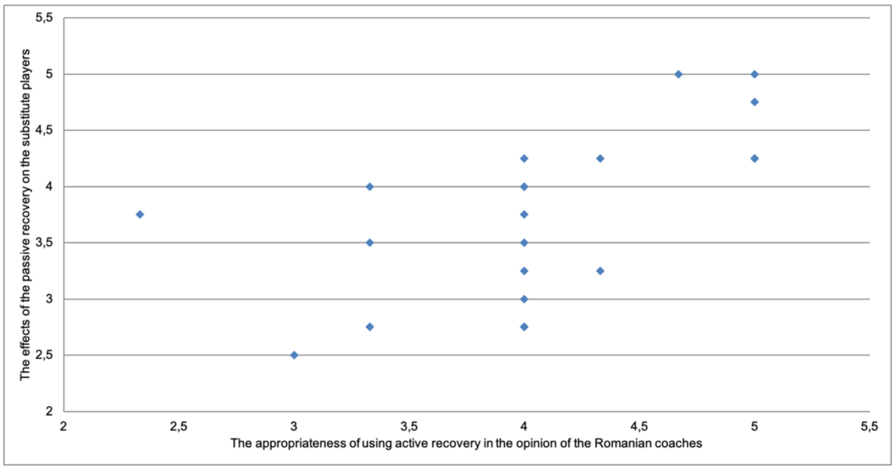


Figure 9. 4. The relationship between the effects of passive recovery and the appropriateness of using active recovery

The relationship between the effects of the passive recovery, on the edge of the court, during matches, in the opinion of the Romanian coaches (C1) and the actual use of the active recovery (PA4)

According to Figure 9. 5, the result of the statistical analysis does not show a statistically insignificant relationship (rho=-0.093; p=0.667), therefore *we cannot conclude that the opinion of the Romanian coaches regarding the effects of the passive recovery on the players on the sidelines is consistent with the effective use of active recovery programs, focused on maintaining the optimal functioning of the athletes' body.*

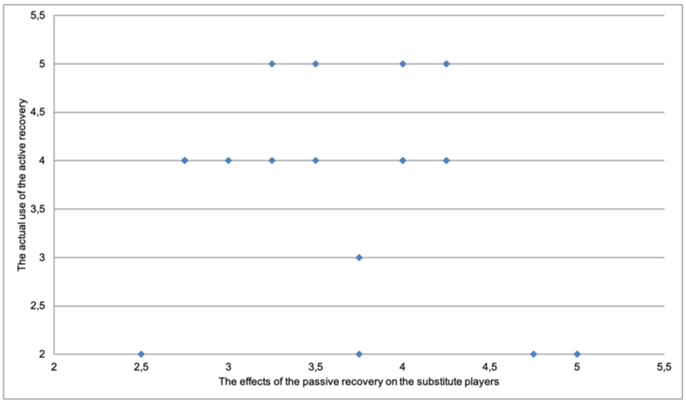


Figure 9. 5. The relationship between the effects of the passive recovery, on the edge of the court, during matches, in the opinion of Romanian coaches and the actual use of the active recovery

9.2. Comparison of the individual FC$_{max}$ values, recorded after the two on-court tests

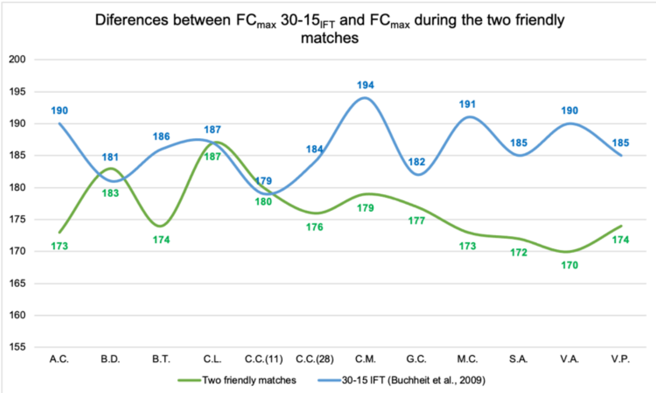


Figure 9. 6. Graphical representation of the different FC$_{max}$ between the 30-15$_{IFT}$ Test during the two friendly matches

Table 9. 1. Statistical results obtained for the 30-15$_{IFT}$ Test and the two friendly matches

Test	X	SD	Min.	Max.	Cv%
FC$_{max}$ 30-15 IFT	186	4.45	179	194	2.39
FC$_{max}$ Friendly matches	176.5	4.96	170	187	2.81

Although the 30-15 $_{IFT}$ test simulates the intermittent effort, specific to the game of handball, according to the data in Table 9. 1, we can see that the players have reached lower values of the FC$_{max}$ during the friendly matches. Only one player recorded identical values of FC$_{max}$ (187 ppm), after both on-court tests. Analyzing Table 9. 1 and Figure 9. 6 we notice a difference of 9.5 ppm between the average of the team obtained after the test (186 ± 4.45 ppm) and the one obtained after the friendly matches (176.5 ± 4.96 ppm). The lowest stress level was reached at 170 ppm during friendly matches, while the maximum stress level was reached during the.30-15 $_{IFT}$ test (194 ppm).

9.3. The processing and statistical interpretation of data collected during physical assessment, under passive recovery conditions

9.3.1. Jump tests

9.3.1.1. The countermovement jump – arms fixed: CMJ AF

Table 9. 2. Statistical comparison of the subjects' performance in the implementation of the passive recovery protocol between the initial and the final testing, concerning the indices of the countermovement jump – arms fixed test (CMJ AF)

	t	Sig. 2-tailed	Average of indices for the CMJ AF test for passive recovery	
			T1 PP (N=12)	T2 PP (N=12)
Jump height (JH)	1.38	0.180	34.57	33.00
RSI1 index	**2.88**	**0.009**	**0.43**	**0.35**
Peak jump power (PP)	**2.24**	**0.039**	**2.71**	**2.55**
Peak velocity of the jump (PV)	1.20	0.242	2.39	2.46

Legend: t = value of t; sig. (2-tailed) = t's level of significance, which must be less than 0.05 for the differences between T1 PP and T2 PP to be statistically significant

The mean obtained for the RSI1 index, in the countermovement jump – arms fixed test *(CMJ AF)* is **highly significantly lower** *(t = 2.88, p. <0.01) in the final testing, when compared to the initial one.* The mean obtained for the index of *peak jump power* (PP), in the countermovement jump – arms fixed test (CMJ AF) **is significantly lower** *(t = 2.24, p. <0.05) in the final testing, when compared to the initial one* (Table 9. 2).

9.3.1.2. The squat jump (SJ)

Table 9. 3. Comparison of the subjects' performance in the implementation of the passive recovery protocol between the initial and the final testing, concerning the indices of the squat jump test (SJ)

	t	Sig. 2-tailed	Average of indices for the SJ test for passive recovery	
			T1 PP (N=12)	T2 PP (N=12)
Jump height (JH)	1.07	0.298	29.99	28.50
RSI1 index	**3.88**	**0.001**	**0.90**	**0.79**
Peak jump power (PP)	**2.28**	**0.033**	**2.49**	**2.32**
Peak velocity of the jump (PV)	1.81	0.084	2.31	2.40

Legend: t = value of t; sig. (2-tailed) = t's level of significance, which must be less than 0.05 for the differences between T1 PP and T2 PP to be statistically significant

The mean obtained for the RSI1 index, in the squat jump test (SJ) **is highly significantly lower** (t = 3.88, p. <0.01) *at the final test, compared to the initial one.* The mean obtained for the index of *peak jump power (PP)* in the squat jump test (SJ) **is significantly lower** (t = 2.28, p. <0.05) *at the final test when compared to the initial one* (Table 9. 3).

9.3.1.3. The medicine-ball right/ left side throw (AMMD/AMMS)

Table 9. 4. Comparison of the subjects' performance in the implementation of the passive recovery protocol between the initial and the final testing, concerning the medicine-ball right hand throw (AMMD) and left hand throw (AMMS) tests

	t	Sig. 2-tailed	Average of indices for the AMMD and AMMS tests for passive recovery	
			T1 PP (N=12)	T2 PP (N=12)
AMMD – peak throw power (PP)	0.42	0.682	10.59	9.97
AMMD – peak throw velocity (PV)	- 0.13	0.894	6.77	6.83
AMMS – peak throw power (PP)	1.27	0.219	9.63	8.36
AMMS – peak throw velocity (PV)	- 1.31	0.204	6.15	6.69

Legend: t = value of t; sig. (2-tailed) = t's level of significance, which must be less than 0.05 for the differences between T1 PP and T2 PP to be statistically significant

Analyzing the data in Table 9. 4, we observe that **there are no significant differences in the physical performance of the subjects during the implementation of the passive recovery protocol between the initial and the final testing**, for any of the 2 indices of the medicine ball right (AMMD) and left throwing tests (AMMS).

9.3.1.4. The 10-meter acceleration test

Table 9. 5. Comparison of the subjects' performance in the implementation of the passive recovery protocol between the initial and the final testing, for the 10 m acceleration test

	t	Sig. 2-tailed	10 m acceleration test for passive recovery	
			T1 PP (N=12)	T2 PP (N=12)
10 m acceleration test	- 1.25	.223	2.14	2.19

Legend: t = value of t; sig. (2-tailed) = t's level of significance, which must be less than 0.05 for the differences between T1 PP and T2 PP to be statistically significant

Analyzing the data from Table 9. 5, we find that **there are no significant differences** in the physical performance of the subjects obtained in the 10 m acceleration test, in the case of applying the passive recovery protocol between the initial and the final test.

9.4. The processing and statistical interpretation of data collected during the physiological evaluation, under conditions of passive recovery

Following passive recovery, the subjects recorded a **regression** of physiological values in the case of 4 indices out of the 5 investigated. Thus, the **heart rate (FC)** recorded an average value of 121.75 ppm after the warm up part, which corresponded to the time of the initial test (T1) and, after 15 minutes of inactivity, the **FC value decreased** to 87.58 ppm. Blood **lactic acid** (AL) levels **dropped** from an average of 1.72 mmol/L (T1) to 1.57 mmol/L (T2) and the concentration of blood **glucose dropped** from 89.58 mg/dL to 88.17 mg/dL. Also, in the case of **body temperature** one may notice a **decrease** from 37.73°C registered after the match warm-up, to a value of 36.09°C, registered after the total inactivity on the substitute benches. The values recorded for **blood oxygen saturation** show a slight **increase** from an average concentration of 98.67% after T1 and of 98.75% after T2.

The averages of all physiological indices recorded decreased in value between the initial test that took place after the match warm-up and the final one, which was performed after 15 minutes of inactivity. Statistical interpretation based on the *t Student test* is presented in Table 9. 6**.**

Table 9. 6. Comparison of the physiological indices of the subjects in the implementation of the passive recovery protocol between the initial and the final testing

	t	Sig. 2-tailed	Average physiological indices for passive recovery	
			T1 PP (N=12)	T2 PP (N=12)
Heart rate (FC)	**11.10**	**0.001**	**121.75**	**87.58**
Lactic acid (AL)	0.97	0.342	1.72	1.57
Serum blood glucose (G)	0.84	0.412	89.58	88.17
Body temperature (Tc)	**18.84**	**0.001**	**37.73**	**36.09**
Oxygen saturation in the blood (S O_2)	- 0.43	0.670	98.67	98.75

Legend: t = value of t; sig. (2-tailed) = t's level of significance, which must be less than 0.05 for the differences between T1 PP and T2 PP to be statistically significant

We find that **there are significant differences** in the implementation of the passive recovery protocol between the initial and the final test, *in terms of 2 of the 5 physiological indices, namely: heart rate ($t = 11.10$, $p < 0.01$) and body temperature ($t = 18.84$, $p < 0.01$).*

9.5. The processing and statistical interpretation of data collected during on-court assessment, under passive recovery conditions

9.5.1. The results of the motor test, on court, under conditions of passive recovery

The individual results recorded by the players following the motor assessment (distance covered and speed), after the 6 sessions of bilateral training game are presented in Annex 10.

Table 9. 7. Cumulative table with the averages of the results of the motor indices specific to the on-court evaluation, after 6 training matches, from the preliminary experiment

SUBJECTS	Average distance covered (km)	Average movement speed (km/h)
	T2 PP	T2 PP
AVERAGE	1.99	7.62
SD	0.14	0.77
min.	1.79	6.6
max.	2.22	8.8
Cv%	7.06	10.09

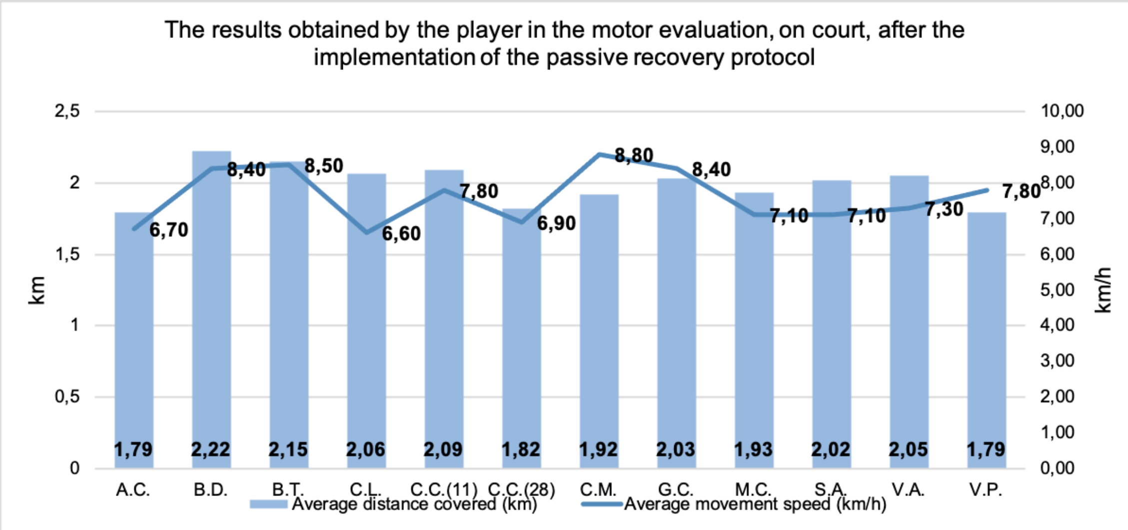


Figure 9. 7. The results obtained by the player in the motor evaluation, on court, after the implementation of the passive recovery protocol

According to Table 9. 7 and Figure 9. 7, the average distance covered after the 6 sessions of 15 minutes of training match, is 1.99 ± 0.14 km, and the average movement speed is 7.62 ± 0.77 km/h. The maximum distance covered is 2.22 km and the minimum is 1.79 km while the speed reaches a maximum of 8.8 km/h and a minimum of 6.6 km/h. The values of the coefficient of variability indicate a **high degree of homogeneity** within the group both for the distance covered (7.06%) and for the speed of movement (10.09%).

9.5.2. The results of the technical-tactical testing, on the court, under conditions of passive recovery

The technical-tactical on-court testing materialized in the quantification of the individual and collective technical-tactical efficiency, by calculating the coefficient of overall efficiency in the game (C.E.T.J.), with the help of the formula elaborated by us.

The results of all the coefficients required for the calculation formula of the C.E.T.J. are presented in the Annex section, as follows:

- the cumulative (individual and collective) observation and calculation sheets for the global efficiency coefficient (C.G.E.), under passive recovery conditions, are presented in Annex 11;
- the cumulative observation and calculation sheets (individual and collective) for the standardized positive action coefficient in the game (C.Ap.S.J.), under conditions of passive recovery, are presented in Annex 12;
- the cumulative (individual and collective) observation and calculation sheets for the standardized in-game error coefficient (C.G.S.J.), under conditions of passive recovery, are presented in Annex 13.

Following Figure 9. 8, we can observe that the **average C.E.T.J. for the whole team, after the 6 sessions of 15 minutes organized by us in the preliminary experiment, has a negative value of -0.22 ± 0.19 points** and varies between a minimum efficiency of -0.52 points obtained by the substitute player on the position of left back and by the on-court player on the right back. The maximum value of the C.E.T.J. is of 0.06 points, being obtained by the on-court player from the center position.

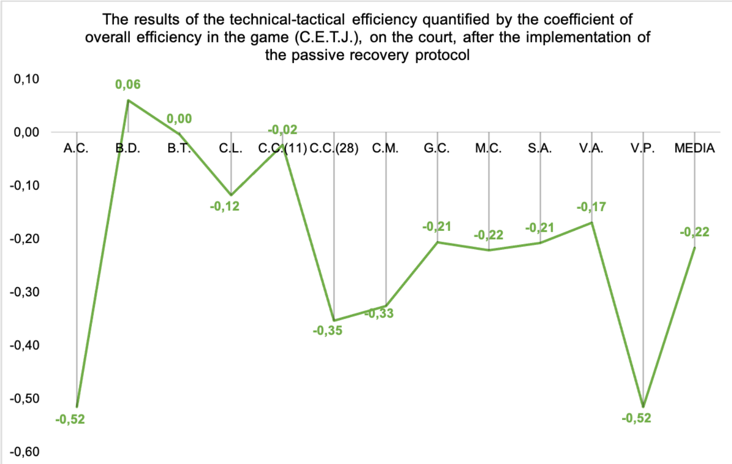


Figure 9. 8. The results of the technical-tactical efficiency quantified by the coefficient of overall efficiency in the game (C.E.T.J.), on the court, after the implementation of the passive recovery protocol

9.6. Analysis of the correlations between the data collected following the evaluations, under conditions of passive recovery

For the correlation analysis, we included only variables whose changes had significant differences between initial and final testing (identified by t tests) and sought to identify statistically significant links between physical and physiological index values recorded before the match and the performances of the athletes on the court, in the conditions in which they entered the effort after a period of complete inactivity.

For the correlation analysis we calculated the Pearson coefficient and the **hypothesis** tested was that *the body's level of preparation for the specific effort of the handball game is significantly associated with the on- court performance of the substitute players.*

9.6.1. Correlations between physical and physiological index values recorded before entering the court and on-court performance

Table 9. 8. Correlations between the values of the variables that underwent significant changes between the initial and final testing, and the performance of the players on the court

		1	2	3	4	5	6	7	8	9
1	Heart rate									
2	Body temperature	***0.93***								
3	CMJ AF Reactive force index	***0.87***	***0.71***							
4	Peak power of the CMJ AF	***0.94***	***0.91***	***0.82***						
5	SJ Reactive force index	***0.96***	***0.92***	***0.79***	***0.96***					
6	SJ Maximum power	***0.94***	***0.91***	***0.83***	***0.98***	***0.95***				
7	Distance covered	***0.96***	***0.94***	***0.78***	***0.94***	***0.99***	***0.93***			
8	Movement speed	0.34	0.43	0.13	0.34	0.38	0.3	0.41		
9	Technical-tactical efficiency in the game (C.E.T.J.)	***0.96***	***0.94***	***0.77***	***0.94***	***0.98***	***0.95***	***0.97***	0.33	

The correlation is significant at a threshold of significance of 0.01 (2-tailed).

Following the multilevel correlation analysis, based on the Pearson *r* correlation coefficient, it was found that **there are statistically significant positive correlations, at a significance threshold p <0.01 between variables that quantify the level of preparation of the body for effort and the performance of on-court players**. However, according to the data in Table 9. 8, we can see that, although the running speed has correlations with all the other variables, they are not strong enough to be statistically significant.

9.6.2. Correlations between the evolution of the values of the physical and physiological indices between the initial and the final test and the performances on the court

Another objective of our research was to investigate *the existence of a link between changes in the values of physical and physiological indices and the performance of players on the court, after the implementation of the passive recovery protocol.*

We started from the assumption that a more pronounced decrease in the body's level of readiness for effort (quantified by physical and physiological indications) as a result of 15 minutes of inactivity during the passive recovery is consistent with a lower level of performance on the court (motor and/or technical-tactical), in matches that are preceded by the passive recovery.

Table 9. 9. Correlations between the decrease in the values of the physical and physiological indices and the efficiency in the game, after the implementation of the passive recovery protocol

		1	2	3	4	5	6	7	8	9
1	Evolution of the FC values									
2	Evolution of the T_c values	0.52								
3	Evolution of the RSI 1 CMJ AF values	-0.3	-0.51							
4	Evolution of the PP CMJ AF values	0.26	-0.27	*0.59**						
5	Evolution of the RSI 1 SJ values	-0.15	-0.24	0.02	-0.02					
6	Evolution of the PP SJ values	0.38	*0.60**	-0.52	-0.24	0.02				
7	Distance covered on the court	*-0.68**	***-0.86*****	0.37	-0.04	0.49	-0.53			
8	Movement speed	-0.21	-0.33	0.39	0.19	0.45	-0.41	0.41		
9	C.E.T.J. PP	***-0.72*****	***-0.91*****	0.41	0.04	0.40	*-0.58**	***0.97*****	0.33	

***** The correlation is significant at a threshold of significance of 0.01 (2-tailed).***

** The correlation is significant at a threshold of significance of 0.05 (2-tailed).*

According to the data in Table 9. 9, ***there are significant correlations between the decrease in the values of physical and physiological indices caused by the period of inactivity on the edge of the handball court and the efficiency of the players on the court, which was assessed in the matches preceded by the passive recovery.***

9.6.3. Correlations between the coefficients measured for the quantification of the technical-tactical efficiency on the court, after the implementation of the passive recovery protocol

In the present study we aimed to find out the relationship between the coefficients calculated to quantify the various technical and tactical actions involving players on the court and their overall efficiency, which was calculated based on the innovative formula designed in our research.

The hypotheses we want to test through correlation analysis are as follows:

- Players who get a higher global efficiency coefficient tend to get a higher overall efficiency coefficient in the game.
- Players who get a standardized positive action coefficient in the game tend to get a higher overall efficiency coefficient in the game.
- Players who get a lower standardized error coefficient in the game tend to get a higher overall efficiency coefficient in the game.

Table 9. 10. Correlations between the coefficients calculated to quantify the efficiency of the players, during the technical-tactical evaluation on the court, after the implementation of the passive recovery protocol (PP)

		1	2	3	4
1	Global efficiency coefficient (C.G.E.)				
2	Coefficient of standardized positive actions in the game (C.Ap.S.J.)	-0.13			
3	The standardized error coefficient in the game (C.G.S.J.)	0.05	0.33		
4	Overall efficiency coefficient in the game (C.E.T.J.)	*0.66**	0.13	*-0.57**	

** The correlation is significant at a threshold of significance of 0.05 (2-tailed).*

We observe in Table 9. 10, that there is a statistically significant positive correlation ($r=0.66$, $p<0.05$), between the global efficiency coefficient (C.G.E.) and the overall in-game efficiency coefficient (C.E.T.J.), but also a statistically significant negative correlation, between the standardized error coefficient in the game and the C.E.T.J. ($r=0.57$, $p< 0.05$).

CHAPTER 10. CONCLUSIONS OF THE PRELIMINARY EXPERIMENTAL RESEARCH, THE NOVELTY AND PROPOSALS FOR PRIMARY RESEARCH

10.1. Preliminary research findings

1) The information base obtained from the opinion questionnaire determined the identification of the need to replace the passive recovery with an active recovery protocol on the edge of the court, during handball matches, specially designed for substitute players.
2) Identifying the maximum values of the heart rate by means of modern technological devices, used during friendly matches, is a valid and reliable method for estimating the maximum effort capacity, in similar conditions to those in official competitions. This aspect provides us with the opportunity to direct the effort from the primary experimental research by referring to the individual FC_{max} values obtained in the friendly matches organized by us.
3) The regression of performance in the case of CMJ AF and SJ is statistically significant and exceeds the regression in the case of the AMM and TA 10 m tests, where the results between the two tests did not show statistically significant differences. This suggests that **inactivity has had a more severe impact on tasks involving explosive power in the lower limbs, such as vertical jumps, than in the upper limbs, such as throwing or those involving speed, such as short-distance, 10 meter accelerations.**
4) The passive recovery implemented between the two tests determined, on average, **the decrease of the subjects' heart rate values by 28%,** which represents an indicator of the regression of their performances. Thus, **the H5 hypothesis of the preliminary experimental research is confirmed.**
5) The passive recovery implemented between the two tests determined, on average, **the decrease of the subjects' body temperature values by a percentage of 4%,** which represents an indicator of the regression of their performances. **Hypothesis I5 of the preliminary experimental research is confirmed.**
6) **The capillary lactate index (AL)** decreased from an average of 1.72 mmol/L (T1) to 1.57 mmol/L (T2), but did not show statistically significant differences ($t = 0.97$, $p = 0.342 > 0.05$). The average values recorded by the players in the case of investigating the dynamics of capillary lactate between the initial and the final test, fall into the category of normal, resting values (1-1.8 mmol/l), which means a low synthesis of lactate. The explanation lies in a very good level of physical training of the players subject to our research and/or a low intensity of effort during the standard match warm-up that does not cause the accumulation of lactate in the blood, above normal values. However, because the passive recovery did not cause the accumulation of lactic acid in the blood, **hypothesis H6 is rejected.**
7) The ***on-court assessment*** involved observing the motor performance and the level of technical-tactical efficiency in the game, **after a passive recovery of 15 minutes**, in the case of all 12 players included in the preliminary research. This approach gave us the opportunity to create a database needed to compare the results that would be obtained by the players in the primary experimental research.
8) The main finding of our preliminary study refers to the significant association between the body's level of preparation for the subsequent physical effort, specific to the game of handball, and the motor and technical-tactical performances of the players on the court. **The more the values of the physical and physiological indices decreased after the passive recovery of 15 minutes, the less we noticed a lower value of the motor and technical-tactical performances of the players on the court.**
9) **The effort reached after the match warm-up (69% of FC_{max}) is an intermediate one, but, after 15 minutes of passive recovery, the value of FC decreased drastically, by 28% below the level reached after warm up, at 87.58 ppm, which means an intensity of 49% of the FC_{max}, which falls into the category of low-intensity efforts.**
10) In our research, **the match warm-up resulted in a body temperature of 37.73 °C, but the passive recovery determined the decrease of the values by 4% below the initial optimal level attained, reaching an average value of 36.09°C.** Reducing the temperature by one degree Celsius causes a 3% decrease in performance (Sargeant, 1987), a fact supported and demonstrated by the results of our research. In conclusion, we can state that the **decrease in physical performance in the jump tests of the handball players after**

the passive recovery can be associated with the concomitant decrease in the physiological body temperature index. Our results are consistent with those obtained in other basketball and football studies that have identified a strong correlation between decreased body temperature and decreased athletic performance in jumping and speed tests (Galazoulas, 2012; Mohr et al., 2004). In addition, the analysis of the correlations between body temperature, heart rate and the performance of on-court players has statistically significant links, which supports the above statements and confirms the results of studies in the game of basketball and football.

11) The efficiency of the players, which was quantified by means of the overall efficiency coefficient in the game (C.E.T.J.) depends to a large extent on the players' goal efficiency following the standardized technical-tactical actions in the game, for each position. **The better the goal efficiency and the fewer standardized errors in the game, the higher the overall efficiency at the end of the matches.**

Based on the analyzed data, we can conclude that the **passive recovery protocol,** implemented after the initial testing performed immediately after the match warm-up (T1 PP) **diminishes the performance and the optimal level of preparation of the players** for the specific effort of handball matches, as demonstrated by their final testing (T2 PP), as well as by the physical evaluation jumps tests (CMJ AF and SJ) and by the tests for the investigation of the physiological parameters (heart rate and body temperature).

10.2. The novelty

We had the opportunity to simultaneously record the results of the players, in a very short time, the accuracy of the data obtained being credited by validation studies of all **portable technological devices** used. The use of these technological innovations is an element of novelty due to the unique way in which information is collected, processed and transmitted to specialists, coaches or athletes, in real time and/or a relatively short time. *Due to their portability and accessibility, micro devices have allowed us to scientifically evaluate physical, technical, tactical or physiological performance under competition-similar conditions*.

The **tests used** in each evaluation protocol to identify changes in the neuromuscular and cardiorespiratory systems after the passive recovery were chosen in accordance with current requirements for handball players from the first minute of official matches, as identified following the study of the specialized literature.

Another novelty was the *biochemical investigation* by collecting blood samples, in the various test moments of our preliminary research, to identify any changes that occurred after the handball players' period of inactivity.

The elaboration of the formula for quantifying the overall efficiency in the game (C.E.T.J.) is an element of novelty proposed by our preliminary research, because it aimed at lending objectivity to the process of the handball players' technical-tactical evaluation, which is often done superficially, only by recording the ratio between the total number of goals and the total number of shots. The results collected at this stage of our research are useful for creating the database that will be used in primary experimental research.

10.3. Proposals for the primary experiment

We aim to maintain the same investigative tools used in the preliminary research because we believe that their variety, accessibility and accuracy have contributed to increasing the interest of female athletes in scientific research, by providing a unique experience of assessing their own performance.

We aim to maintain the same sample of players in the primary experiment, as we intend to perform a comparative analysis of the individual results obtained in both evaluation conditions (passive recovery and active recovery conditions).

As the space on the side of the handball court is small, we will aim to develop an active recovery protocol that contains accessible, efficient and easy to implement means in small spaces.

PART III: THE PRIMARY RESEARCH ON THE DEVELOPMENT AND IMPLEMENTATION OF THE ACTIVE BREAK PROTOCOL ON THE EDGE OF THE HANDBALL COURT, IN ORDER TO MAINTAIN THE EFFECTS OF THE MATCH WARM UP ON THE BODY

CHAPTER 11. THE METHODOLOGICAL OPERATIONAL APPROACH OF THE PRIMARY EXPERIMENTAL RESEARCH

11.1. The prerequisites of the primary experimental research

- During handball competitions, fatigue is the consequence of the stresses imposed by the game specific effort and it is accumulated progressively throughout the match, especially towards the end of it.
- Restoring the body by restoring energy potential and functional capabilities during matches can only be achieved through an optimal ratio of effort and rest that is possible by the efficient rotation of players. The unlimited exchanges allowed in the game of handball, allow the coaches to control the times during which the players evolve or rest and an effective ratio between the two situations can optimize the individual or collective performances during the matches.
- The efficient rotation of the players presupposes both a high value homogeneity on positions and an optimal level of the body's preparation for the subsequent effort in the case of the substitute players, which can be obtained only by going through a warm-up program.
- The requirements to which the exchange players are subjected, refer to the fast adaptation to the rhythm of the game and to the resolution with maximum efficiency of all the stresses imposed from the first seconds of the game.
- In order to maintain the physical and physiological potential for effort of the players who do not enter the game from the first minute, it is necessary to continue warming the body on the edge of the court. Handball coaches are greatly interested in this aspect, considering that the active recovery is highly appropriate for maintaining the physical and mental state at an optimal level for entering the court.
- Continued warm-up on the court edge can contribute to optimizing the performance of the substitute players on the court when the opportunity arises for them to enter the match.
- Decreased values of the heart rate and body temperature physiological indices due to inactivity, slow down the metabolic processes of providing the necessary ATP and PC resources to the neuromuscular system and, consequently, the power and speed of muscle contraction in the lower limbs decreases.
- Physical activity strategies implemented during the transition periods, between the end of the warm-up and the beginning of the match for the substitute players, can help maintain or attenuate the percentage of physical and physiological performance regression caused by the passive recovery, imposed by regulation, on the edge of the handball court.

11.2. Objectives of the primary experimental research

- The elaboration of the methodology necessary for the implementation of the active recovery protocol on the edge of the handball court, by selecting and adapting the course of action, in full correlation with the physical and functional particularities of the players, identified following tests and the statistical analysis of their results, from the preliminary experimental research.
- Choosing the appropriate method of calculating the maximum heart rate (FC_{max}), for each player, in order to direct the intensity of the effort from the active recovery, towards maintaining aerobic capacity, at a level of 60% of 60% of FC_{max}.
- Identifying the values of the physical and physiological indices before and after the implementation of the active recovery protocol (at the time of T2 PA testing) and observing their evolution between the two tests (T1 PA and T2 PA), through statistical analysis.
- Maintaining the heart rate at 60% of the maximum aerobic capacity, intensity established based on the recommendations in the specialized literature, but also on the results obtained in our preliminary research.
- Maintaining the values of the physical indices specific to the effort anaerobic power, from the level of the lower limbs, in optimal parameters, through the intensity of effort proposed in the active recovery protocol.

- Maintaining the physical indices specific to the explosive power required for jumping and throwing, at values similar to those obtained after the standard match warm-up.
- Maintaining body temperature at values similar to those obtained after standard match warm-up.
- Achieving superior performance in the technical-tactical evolution of the players, quantified by the coefficient of overall efficiency in the game.
- Increasing the technical-tactical efficiency of the players in the standardized actions in the game, increasing their involvement in the standardized positive actions in the game and reducing the number of standardized errors in the game, so that the overall efficiency coefficient in the game increases significantly compared to the values obtained after implementing the passive recovery protocol.

11.3. The purpose of the primary research

The aim of the primary research is to develop and implement an active recovery protocol on the edge of the handball court, focusing on maintaining the benefits of match warm-ups, which will increase the players' performance on the court, thus replacing complete inactivity on the bench, prior to the specific effort of handball matches.

11.4. Tasks of the primary experimental research

- The development of a strategy to replace the passive recovery after the match warm-up with an active recovery protocol, which would include a physical activity program on the edge of the handball court, for all players included in the research.
- Choosing a method for determining the optimal intensity of effort during the active recovery program, based on information from the specialized literature and using the database collected in the preliminary experiment.
- The choice of accessible means, which can be used in small spaces, necessary for the active recovery program.
- The implementation of player evaluation protocols in organization and testing conditions identical with those of the preliminary experiment.
- Recording the players' results using the same methods and unconventional means of evaluation from the preliminary experimental research, at different times of testing, which provide relevant information about the evolution of physical and physiological indices and their influence on court performance, under active recovery conditions.
- Implementation of the active recovery protocol, according to the functional features specific to the players included in our research.
- Recording and highlighting the changes made by 15 minutes of active recovery on the values of the physical and physiological indices and comparing them with the values obtained after the match warm-up.
- Completing the individual sheets for calculating the efficiency with the help of the C.E.T.J. formula, in view of the video analysis of all the 6 sessions of the bilateral training match, organized by us in order to evaluate the players on the court.
- The processing and interpretation of data obtained from physical and physiological evaluations on the edge of the court and from the evaluation of motor and technical-tactical on-court efficiency.
- Comparing of the impact of the two recovery protocols' implementation (passive and active), by analyzing the existence of statistically significant differences between the players' performances obtained in the initial tests (T1 PP with T1 PA), in the final tests (T2 PP with T2 PA) and between the evolution of these performances (T2-T1 PP with T2-T1 PA), in terms of specific indices of jumping, medicine ball throwing and the values obtained in the 10 m Acceleration Test, as well as the FC, AL, G, Tc and SpO_2 physiological indices.
- Analyzing of the existence of some significant differences between the performance of the players obtained in the case of the implementing the passive recovery protocol and the active recovery protocol (PP with PA), regarding the motor and technical-tactical evaluation tests on the court.
- Formulating the conclusions of the primary experimental research.

11.5. Primary experimental research hypotheses

The **general** hypothesis of the research is based on the assumption that *the motor performance and technical-tactical efficiency on the court of substitute handball players can be improved by replacing inactivity on the edge of the court with an active recovery protocol, which involves pedaling stationary bicycles at an intensity of FC_{max} and thus contributes to maintaining or mitigating the decrease in physical and physiological benefits on the body of the standard match warm up.*

The ***specific*** hypotheses tested in the primary experimental research are as follows:

- ***H 1.1.*** Unlike the inactivity specific to passive recovery, the implementation of the active recovery protocol, after the standard match warm-up, based on methods and means adapted to the individual peculiarities of the players, determines the maintenance or attenuation of the decrease in the level of performance with physical tasks and tests.
- ***H 1.2***. The choice, set up and use of the technological devices according to the individual characteristics of the players, allow the monitoring of effort parameters and their maintenance within the limits established by our research methodology.
- ***H 1.3.*** Physical activity at an intensity of 60% of FC_{max} will speed up the elimination of lactic acid from the blood.
- ***H 1.4.*** Establishing the intensity of the effort, at an average value of 60% of the FC_{max}, will allow the active recovery program to be carried out in conditions of real balance between the requirements and the oxygen supply, without the appearance of the state of fatigue.
- ***H 1.5***. Unlike the inactivity specific to passive recovery, optimizing the level of effort during the active recovery, by setting the intensity of the effort at 60% of the maximum aerobic potential, determines the maintenance or attenuation of the decrease in body temperature values obtained after the standard match warm-up.
- ***H 1.6.*** Following the active recovery protocol, the players will run longer distances and at higher speeds than those recorded after the period of inactivity.
- ***H 1.7***. Compared to the inactivity specific to passive recovery, maintaining the effort capacity at 60% of the maximum individual potential, by using the active recovery protocol on the edge of the handball court, determines an increase in the technical-tactical efficiency on the court, of the handball players.

11.6. Battery of tests and investigations used in the primary experimental research

In the primary experimental research, we used the following **physical tests**, focused on assessing the combined quality of strength-speed, both in the lower limbs and in the upper limbs. All these tests were also used in the preliminary research.

The **physiological investigations** for the primary experimental research consisted of monitoring and analyzing functional and biochemical indices, as follows: heart rate, body temperature, lactic acid, serum glucose and blood oxygen saturation.

The **on-court assessment** consisted of identifying the total distances covered, the movement speed and the values of the overall efficiency coefficient in the game.

11.7. The equipment and materials necessary for the primary experimental research

In order to fulfill the objectives and tasks proposed in the primary experimental research, we decided to use all the research devices and tools used in the evaluation protocols in our preliminary approach and we supplemented the material base with new research equipment and applications, which will be presented below.

11.7.1. The stationary exercise bike, Progressive SX2000

The Progressive SX2000 bike (Figure 11. 1) is a model of bicycle with friction resistance, which means that it has brake pads (of felt) that are connected to a 15 kg flywheel and the resistance is adjusted by the control lever, intuitively placed under the handlebars.

The construction of the bike is compact and it has the following physical dimensions: height, 115 cm, width, 50 cm, depth, 115 cm and weight, 27 kg. The saddle is adjustable in two directions, up-down (range 75-99 cm) and back-front, the handlebar can be adjusted vertically, up-down (range 99-112) and for good stability, you can adjust the feet height.

The reason why we chose to include the stationary bike in the organizing methodology of the active recovery protocol is the accessibility with which it can be used and the small size that allows placement in narrow spaces. In addition, our goal of keeping players active on the edge of the court can be achieved by working in one place without leaving the area.

Figure 11. 1. The dimensions of the stationary training bike Progressive SX2000, photo source, https://beprogressive.ro/products/sx2000

The **technology** of this training device allows the tracking of effort parameters through the LCD monitor placed on the handlebars or by establishing a **connection to the tablet or phone**, devices that can be placed on the special support. This way, the activity can be monitored in real time, the data on time, speed, distance, calories, cadence and pulse, being displayed on the smart interface of the bike's digital monitor or on the screen of the connected device.

The bike has modern features because it can be connected via Bluetooth or directly via cable to mobile applications such as **Kinomap**, Zwift, FitShow, compatible with smartphones or tablets, which have Android or iOS operating systems. Regardless of the device used for data sharing or the chosen mobile application, it is necessary to create a personal account, where the parameters of the effort can be tracked in real time or stored in the history of the activities performed.

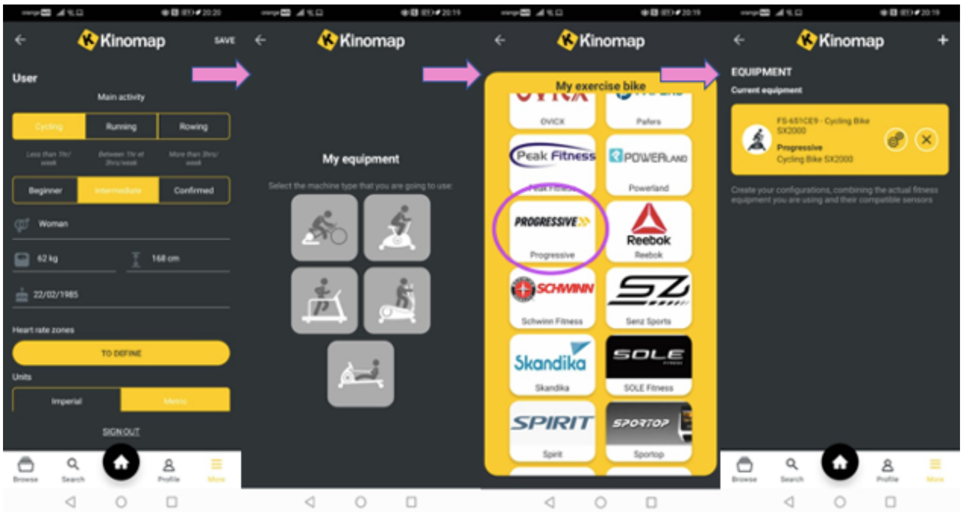


Figure 11. 2. The necessary steps to connect the Progressive SX2000 bike to the Kinomap mobile application (setting personal data, choosing the equipment used, choosing the brand of the equipment used, and the identification of the equipment by the application)

In the primary experimental research, we chose to share data recorded during activities on Progressive SX2000 bikes to the Kinomap mobile app, the 2.30.4 version, from 2021. For the **Kinomap** app to identify and connect to a specific device, it is necessary to activate the Bluetooth function of the phone, at which point the bike model is recognized and the available sensors are connected. The necessary steps for connecting the Progressive bike are shown graphically in Figure 11. 2.

11.8. Sample group, location and stages of the primary experimental research

In order to carry out a unitary comparative analysis, the same 12 players who participated in the preliminary experimental research were included in the primary experimental research. As in the case of the preliminary research, the primary experiment was a longitudinal one, taking place during the second leg of the 2020-2021 competition season. The experimental approach was carried out both in the "Danube" Sports Hall on Stadionului Street, no. 1-7, 2-8, Galați, as well as in the "Siderurgistul" Sports Hall with the address on 2 Strada Street, Galați.

The primary experiment was started in December 2020 and was completed in June 2021, a period that corresponded to the second leg of the women's handball competition season, 2020-2021 edition.

The **stages** of the primary experimental research were the following:

Stage I: (2 – 12 December 2020) was scheduled to continue and supplement the sources from specialized literature.

Stage II: in the interval (14 - 23 December) the structuring and elaboration of the plan for carrying out the primary experimental research.

Stage III: January 5 - February 16, 2021, we carried out the physical and physiological evaluations, in conditions of active recovery;

Stage IV: March 6 - May 31, 2021 - we implemented the on court evaluation (motor and technical-tactical) of the players, by organizing bilateral training games, in conditions of active recovery;

Stage V: June 1 - September 1, 2021:

- analysis, interpretation and statistical comparison of the results obtained by the players in the evaluations implemented in both recovery conditions (passive and active);
- formulating conclusions and recommendations;
- writing the doctoral thesis.

11.9. Development, organization and implementation of the active recovery protocol, specific to the primary experimental research

11.9.1. Choosing the type of physical activity from the active recovery protocol

Given that the passive recovery implemented in our preliminary research has led to a significant decrease in the values of physical indices in jump tests, *we considered that pedaling on stationary bikes could be the most effective means of action*, because it is focused primarily on the muscles of lower limbs.

Another aspect that we took into account in choosing the activity of pedaling on stationary bikes was the possibility to predetermine the intensity of the effort and to control in real time the parameters of effort, by modern technological means.

The ratio of the effort intensity on stationary bicycles to the maximum aerobic capacity was based on the recommendations from the specialized literature, the upper limit of the recommended intensity for the effort made during the active recovery periods being 60% (Yanaoka, Hamada, et al., 2018).

11.9.2. Determining the intensity of the effort on stationary bikes

The methods and means used to determine FC_{max} are accessible, minimally invasive, involve lower costs and do not require authorized personnel and, therefore, FC_{max} determination is preferred among researchers in most sports.

11.9.3. Choosing the calculation method for the maximum heart rate (FC_{max})

The choice of the most appropriate method for determining the maximum heart rate was a task that involved both the study of the literature and the analysis of the databases collected from the on-court tests in our preliminary study (the 30-15 $_{IFT}$ test and the two friendly matches).

The studies identified in the literature propose numerous calculation formulas for estimating the maximum value of the heart rate. We decided to submit to analysis 3 of them: the one proposed by Karvonen et al. (1957), the one proposed by Londeree & Moeschberger (1982) and the one proposed by Shargal et al. (2015). Because we wanted to reduce the risk of indirectly influencing the results by applying general formulas (such as those suggested by the literature), we also included in the process of choosing the method for calculating effort intensity the results obtained by us in the preliminary research, obtained by players in the on-court tests (the 30-15$_{IFT}$ test and the two friendly matches). Unlike the estimation by calculation formulas, the determination of FC_{max} based on the on-court tests was done using Garmin Fenix 5S smartwatches.

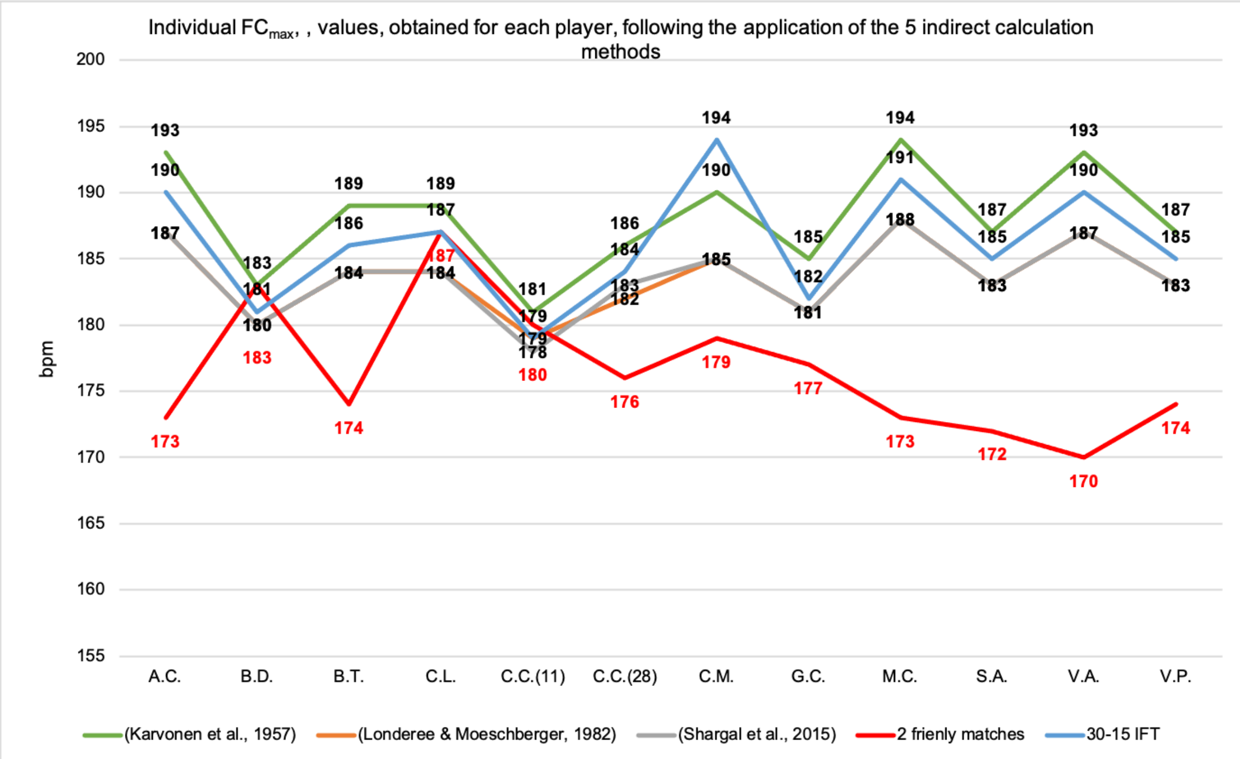


Figure 11. 3. Graphical representation of FC_{max}, values, obtained for each player, following the application of the 5 indirect calculation methods

Figure 11. 3 provides a clear picture of the calculations made to determine the maximum values of the individual heart rate, in the case of all 12 players included in our experimental research. Thus, we can observe that the 3 mathematical calculation formulas provide data similar to those obtained after the 30-15$_{IFT}$ Field Test but the data recorded after the two friendly matches show much lower values of FC_{max} for 9 of the 12 players. After analyzing all 5 methods of calculating the maximum aerobic capacity by reference to the heart rate index, *we decided that the values obtained from the two friendly handball matches are the most suitable data that we can use to determine the intensity of effort, in the primary experiment.*

11.9.4. Organizing and implementing the active recovery protocol

In our research, we used the stationary bike, in order to maintain the benefits of the match warm up, by continuous pedaling, for 15 minutes, at an effort intensity of 60% of the maximum aerobic potential, this being previously established by reference to the heart rate frequency (FC_{max}), recorded during the friendly handball matches.

Figure 11. 4, shows our intervention, which meant replacing the passive recovery on the bench with a stationary bike pedaling program, which we called the active recovery.

Figure 11. 4. Photographic representation of the differences between the passive recovery and the active recovery

In order to familiarize the players with the work procedures, we carried out a training session during which the use of the necessary devices and devices was detailed. At this stage of our research, the athletes were trained to control the intensity of the effort when cycling, by monitoring the heart rate index on the screen of the Garmin Fenix 5S watch, a device already known and used since the preliminary research. At the beginning of the active recovery program, the indoor cycling activity was set from the activity menu displayed on the watch screen and, in this way, the heart rate data could be monitored in real time.

Once the value of the tracked heart rate stabilized, the players cycled for 15 minutes and with the Kinomap application, we were able to track and record the following parameters of effort on the bike: pedaling power (watts), rotations per minute (rpm) and pedaling speed (km/h). It is important to note that all the sportswomen used their own phones to connect the bikes via Bluetooth to the Kinomap application, for which individual accounts were created. In this way, each player was able to monitor on the phone screen, in real time, the parameters of the effort made during the 15 minutes of cycling. The power, cadence and speed parameters were adjusted by adjusting the brake pad control lever, according to the oscillation of the heart rate index, monitored by the Garmin Fenix 5S watches.

During the 14 interventions in the primary experimental research, which included evaluation protocols in active recovery conditions, we kept the same instructions as during the familiarization bikes training, and the players were encouraged to follow the recommendations to maintain the parameters of cadence, power and speed, within the limits necessary to maintain the heart rate at 60% of the maximum value.

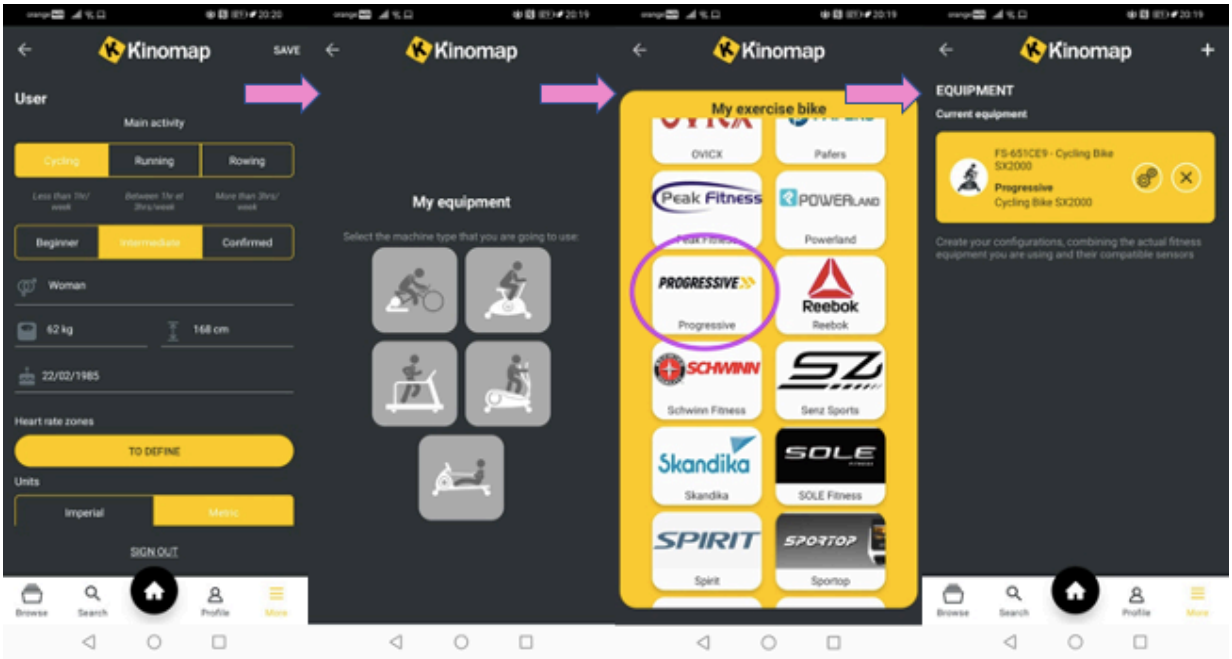


Figure 11. 5. Necessary steps to connect the Kinomap mobile app to the Progressive SX2000 stationary bike

Figure 11. 5, shows the steps taken to connect the Kinomap mobile app to the Progressive SX2000 stationary bikes. Initially, an account is created based on the e-mail addresses of the athletes and then the application is opened. From the user profile settings, the type of activity, fitness level, gender, weight, height, age and desired metric system are chosen. After establishing these settings, the type of equipment used and the model are chosen, and then the connection via Bluetooth is made and the bike is recognized. Thus, data sharing begins.

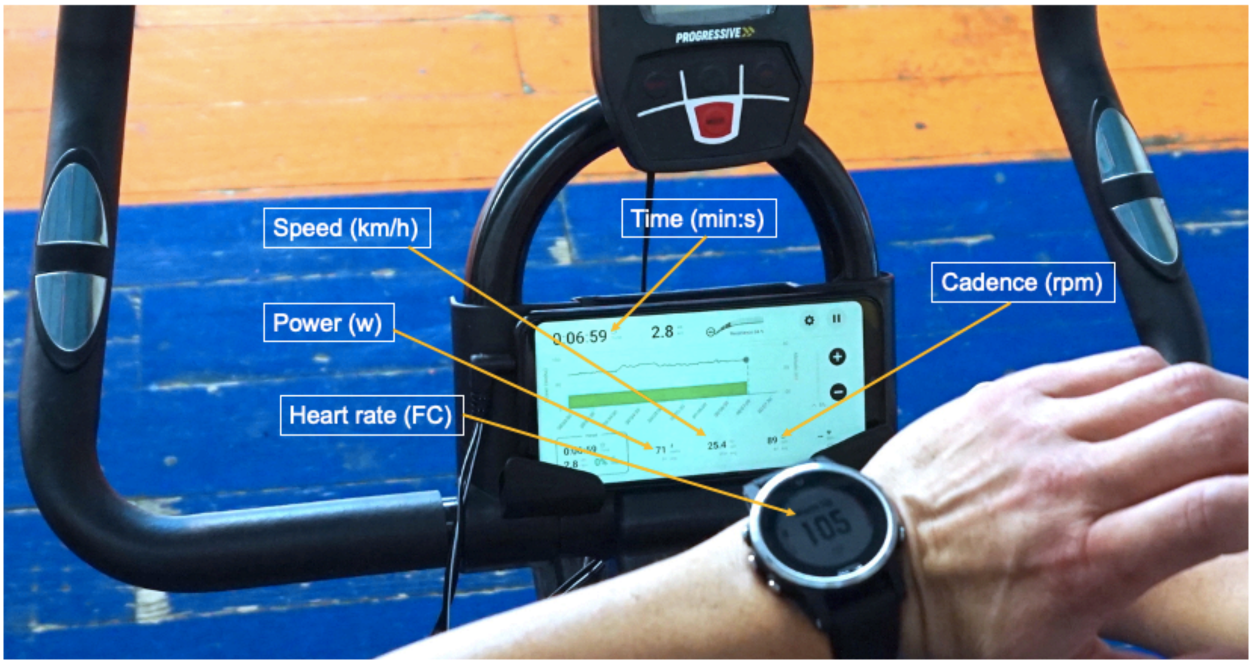


Figure 11. 6. Monitoring the parameters of effort during the active recovery, by means of technological devices

In Figure 11. 6, we exemplified the working procedure by combining the methods of monitoring all the effort parameters, during the pedaling activity, applied during our interventions, from the primary experiment. Thus, the heart rate could be monitored on the screens of the Garmin Fenix 5S watches, which were set to the “indoor pedaling” activity, while the pedaling time, power, speed and cadence were monitored via the Kinomap application, installed on players' phones, which were also connected to the Progressive SX2000 stationary bikes.

11.10. General strategy for the implementation of evaluation protocols, in the framework of the primary experimental research, under conditions of active recovery

Our intervention consisted in the implementation of the active recovery protocol instead of the inactivity imposed on the edge of the court, according to the regulations for the organization and conduct of handball competitions, and it took place in the second leg of the 2020-2021 competition season.

Table 11. 1. Locating our interventions, according to the structure of the 2020-2021 competition season, in the National Women's Handball League

MACROCYCLE 1								MACROCYCLE 2			
JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Training period				Competition period	Transition period	Training period		Competition period			

As it can be seen in Table 11. 1, our interventions coincided with the second training period and the second competitive period, specific to the 2020-2021 championship edition. The middle of November and December were devoted to bibliographic study and discussions with the team's coaches in order to plan further activities. Moreover, during this period, we participated in the training of the players and we provided additional explanations related to the purpose of the primary experimental research. Between January and May 2021, we carried out the 3 types of evaluation, under the conditions of the active recovery protocol implementation.

In order to attain a clear picture of the effects of replacing the passive recovery with the active recovery, we considered it necessary to apply the same approach used in the preliminary experimental research, for the implementation of all evaluation protocols. The test times, samples and investigations applied are schematically represented in Figure 11. 7.

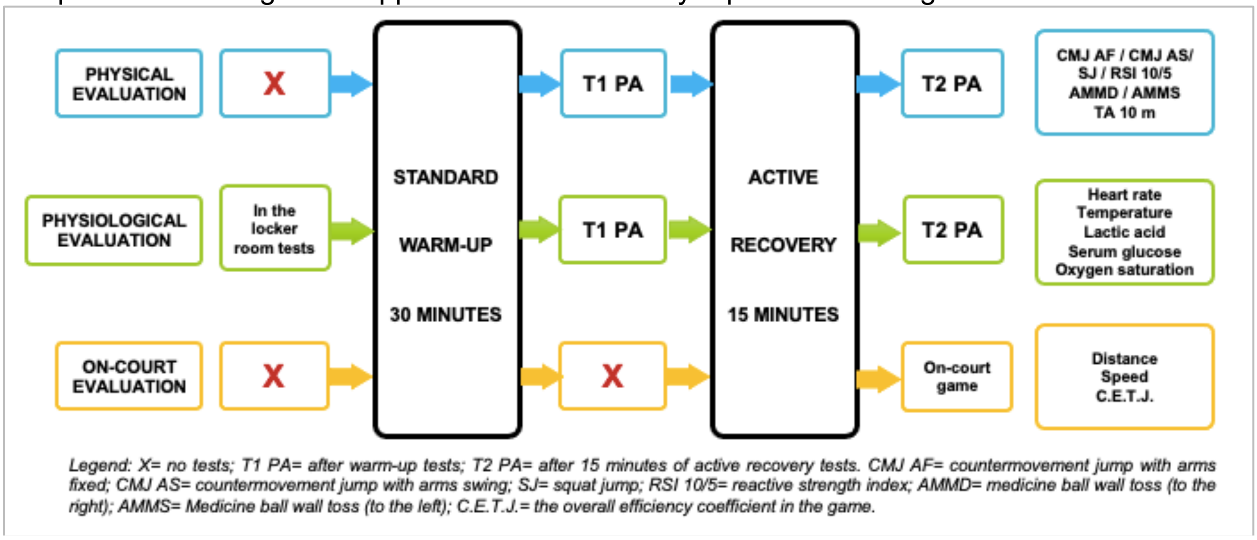


Figure 11. 7. The steps taken in the case of evaluations made for the preliminary research, under the conditions of the active recovery's implementation

Analyzing Figure 11. 7 we can note that, as in the preliminary research, the physiological evaluation consisted of three testing moments, the physical one was implemented in two testing moments and the on-court test consisted in the analysis of bilateral games on the court.

11.10.1. Planning the physical, physiological and on-court assessments, under active recovery conditions

The scheduling and planning of the evaluation days within the preliminary research was done both according to the match schedule established for the second leg of the 2020-2021 competition season, and the weekly training program of the team, established by the team coach.

Table 11. 2. Locating our interventions through physical evaluation, within the primary experiment

JANUARY 2021 - PREPARATORY PERIOD + COMPETITION PERIOD PHYSICAL EVALUATION				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
11 January	Monday	9:00-10:30	Group 1	CMJ AF / CMJ AS
13 January	Wednesday	15:30-17:00	Group 1	SJ / RSI 10/5
15 January	Friday	9:00-10:30	Group 1	AMMD / AMMD / TA 10 m
18 January	Monday	9:00-10:30	Group 2	CMJ AF / CMJ AS
20 January	Wednesday	15:30-17:00	Group 2	SJ / RSI 10/5
22 January	Friday	9:00-10:30	Group 2	AMMD / AMMD / TA 10 m
FEBRUARY 2021-COMPETITION PERIOD PHYSIOLOGICAL EVALUATION				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
9 February	Tuesday	9:00-10:30	Group 1	FC / Tc / AL / G / SpO_2
16 February	Tuesday	9:00-10:30	Group 2	FC / Tc / AL / G / SpO_2
MARCH 2021-COMPETITION PERIOD ON-COURT EVALUATION				
Date	**Day**	**Time slot**	**Group**	**Tests performed**
6 March	Saturday	11:30-13:30	Both groups	**Match 1** Distance / Speed/C.E.T.J.
20 March	Saturday	11:30-13:30	Both groups	**Match 2** Distance / Speed/C.E.T.J.
APRIL 2021-COMPETITION PERIOD ON-COURT EVALUATION				
3 April	Saturday	11:30-13:30	Both groups	**Match 3** Distance / Speed/C.E.T.J.
17 April	Saturday	11:30-13:30	Both groups	**Match 4** Distance / Speed/C.E.T.J.
MAY 2021-COMPETITION PERIOD ON-COURT EVALUATION				
8 May	Saturday	11:30-13:30	Both groups	**Match 5** Distance / Speed/C.E.T.J.
29 May	Saturday	11:30-13:30	Both groups	**Match 6** Distance / Speed/C.E.T.J.

According to Table 11. 2, it can be seen that the physical evaluation occurred in January 2021, when the players were in the training period during the first part of the month, the official matches resuming with the second half of the month. During this period, we also carried out the training for purposes of familiarization and to establish the values of the effort parameters that needed to be achieved during the activity on bicycles, during the primary experiment itself.

The physiological evaluation occurred in February and corresponded to the competitive period of the championship second leg.

Both during the physical assessment and the physiological assessment, the players were tested according to the groups established in the preliminary experimental research. We used this group assessment system to reduce the risk of influencing the results with a too long waiting time between the end of the active recovery protocol and the actual testing of the players.

In the case of the evaluation on the court, after the standard match warm up, all the players went through the active recovery protocol at the same time, and after 15 minutes of cycling on stationary bikes, both groups were tested on the court, by means of the bilateral handball game, lasting 15 minutes.

CHAPTER 12. RESULTS OF THE PRIMARY EXPERIMENTAL RESEARCH

In the primary experimental research, the players were tested following, in general, the same evaluation structure as in the preliminary experimental research. The main difference was that the passive recovery between the two test moments was replaced by an active recovery protocol, implemented instead of the substitute benches.

12.1. Processing and statistical interpretation of data collected following the physical evaluation, under active recovery conditions

All the results obtained by the 12 players in the physical tests, namely the countermovement jump - arms fixed (CMJ AF), countermovement jump with swinging arms (CMJ AS), the squat jump (SJ), the RSI 10/5 jump, the medicine-ball side throw (right and left) and the 10 m Acceleration Test are presented in Annex 15.

12.1.1. The jump tests

12.1.1.1. The countermovement jump - arms fixed: CMJ AF

Following the analysis of the *t test*, **there are no statistically significant differences** in the physical performance of the subjects in the case of applying the active recovery protocol between the initial and the final testing, for any of the 4 indices of the countermovement jump - arms fixed test (CMJ AF).

12.1.1.2. The squat jump (SJ).

There are no significant differences in the physical performance of the subjects when applying the active recovery protocol between the initial and the final testing, for any of the 4 indices of the squat jump test (SJ).

12.1.2. The medicine-ball right/left side throw (AMMD/AMMS)

There are no significant differences in the physical performance of the subjects in the case of the implementation of the active recovery protocol between the initial and the final testing, for either of the 2 indices of the medicine-ball right hand (AMMD) and left hand throw (AMMS) tests.

12.1.3. The 10-meter acceleration test

There are no significant differences in the physical performance of the subjects obtained in the 10 m acceleration test, in the case of applying the active recovery protocol between the initial and the final testing.

12.2. The processing and statistical interpretation of data collected following the physiological evaluation, under active recovery conditions

The individual results obtained by the players in the physiological evaluation in all three tests performed in the primary experimental research are presented in Annex 16. The statistical analysis of the physiological data was performed only for the post-match-warm-up test (T1 PA) and for the one after the implementation of the passive recovery (T2 PA).

According to the results presented in Figure 12. 1, the averages of the physiological indices recorded different values between the initial testing which occurred immediately after the match warm-up and the final one, which occurred after 15 minutes of pedaling at an effort intensity of 60% FC_{max}. The statistical interpretation based on the *t Student test* is presented in Table 12. 1

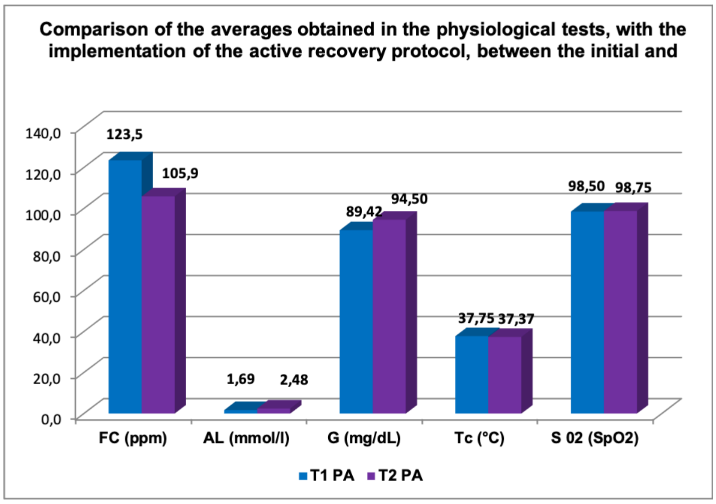


Figure 12. 1. Comparison of the averages obtained in the physiological tests, with the implementation of the active recovery protocol, between the initial and the final testing

Table 12. 1. Comparison of the subjects' physiological indices with the implementation of the active recovery protocol between the initial and the final testing

	t	Sig. 2-tailed	Average physiological indices in case of active recovery	
			T1 PA (N=12)	T2 PA (N=12)
Heart rate (FC)	**8.83**	**0.001**	**123.5**	**105.90**
Lactic acid (AL)	**- 3.37**	**0.003**	**1.69**	**2.48**
Serum glucose (G)	**- 3.64**	**0.001**	**89.42**	**94.50**
Body temperature (Tc)	**2.89**	**0.008**	**37.75**	**37.37**
Oxygen saturation in the blood (S O2)	1.25	0.223	98.50	98.75

Notes: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between T1 PA and T2 PA to be statistically significant

Analyzing the data in Table 12. 1, we find that **there are significant differences in the implementation of the active recovery protocol between the initial and final testing**, in terms of 4 of the 5 physiological indices, respectively: *heart rate (FC), lactic acid (AC), serum glucose (G) and body temperature (T_c).*

The mean of the *heart rate (FC)* physiological index is **highly significantly lower (t = 8.83, p. <0.01) at the final testing compared to the initial testing**. The active recovery implemented between the two tests determined, on average, a decrease in the heart rate of the subjects, but the **average value of the team, 105.9 ppm reached after completing the active recovery protocol is the one we followed in the primary experiment and, therefore, we cannot state that the subjects recorded a decrease in performance, but rather maintained the FC values at the optimal level calculated by us, for entering effort. The value of 105.9 ppm corresponds to the effort intensity of 60% FC_{max}.**

The average of the *lactic acid (AL)* physiological index is **highly significantly higher** (t = -3.37, p. <0.01) **at the final testing, when compared to the initial one**. The active recovery implemented between the two tests determined, on average, the **increase** of the subjects' **lactic acid** values.

The mean *serum glucose (G)* physiological index is **highly significantly higher** (t = -3.64, p. <0.01) **at the final testing, when compared to the initial testing**. The active recovery implemented between the two tests determined, on average, the **increase** of the subjects' **serum glucose** values.

In the case of *body temperature (T_c)*, the mean is **highly significantly lower** (t = 2.89, p. <0.01) **at the final testing when compared to the initial one**. The active recovery implemented between the two tests determined, on average, the **decrease** of the subjects' **body temperature** values.

Based on the analyzed data, we can conclude that the active recovery protocol, consisting of 15 minutes of warm up at an effort intensity of 60% of FC_{max}, implemented after the initial testing performed after the match warm-up (T1 PA), significantly modifies the physiological responses of the players, but maintains the body's level of preparation for the effort specific to handball matches, in optimal parameters, as shown by their final testing (T2 PA), namely, by the physiological indicators related to heart rate, lactic acid, serum glucose and body temperature.

12.3. The processing and statistical interpretation of data collected following on-court assessment, under active recovery conditions

12.3.1. The results of the motor testing, on the court, under conditions of active recovery

The individual results recorded by the player in the motor assessment (distance covered and speed), after 6 sessions of bilateral training game, played in the primary experiment, are presented in Annex 17.

Table 12. 2. Cumulative table with the averages of the results of the motor indices specific to the on-court evaluation, after 6 training matches, from the primary experiment

SUBJECTS	Average distance covered (km)	Average movement speed (km/h)
	T2 PA	T2 PA
AVERAGE	2.25	7.78
SD	0.16	0.76
min.	2.05	6.8
max.	2.56	8.8
Cv%	7.11	9.77

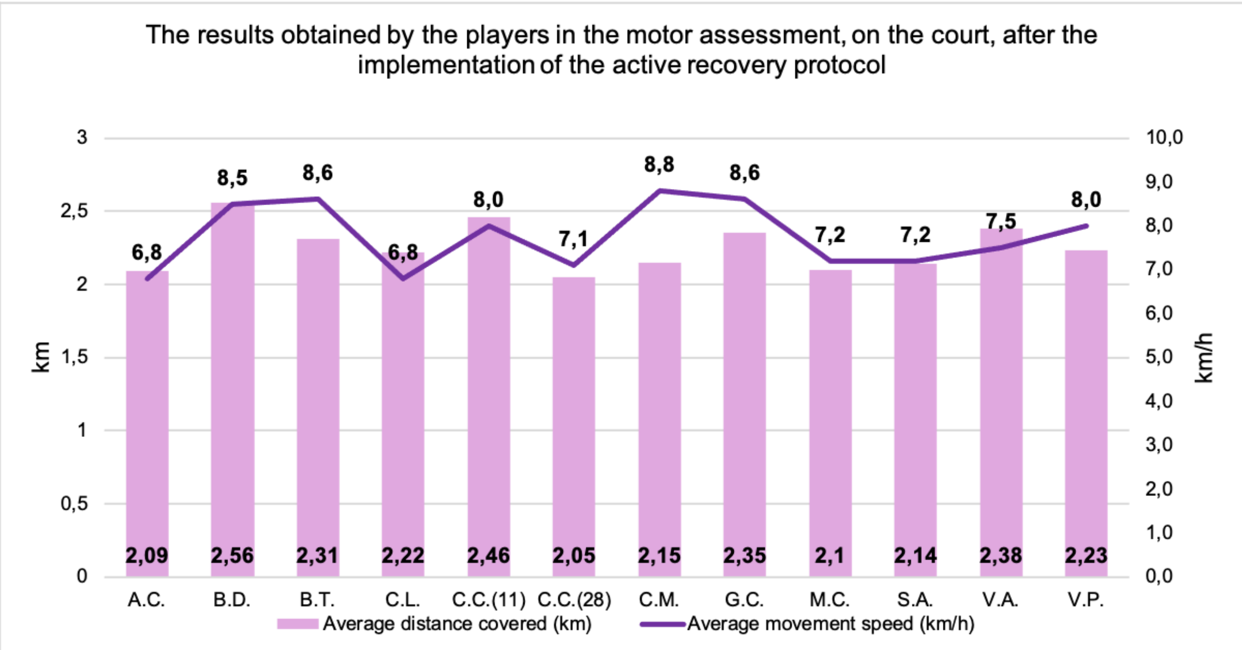


Figure 12. 2. The results obtained by the players in the motor assessment, on the court, after the implementation of the active recovery protocol

Analyzing Table 12. 2 and Figure 12. 2, we notice that after implementing the active recovery protocol, the *average distance covered* in the 6 sessions of 15 minutes each of the training match is 2.25 ± 0.16 km, and the *average speed* is 7.78 ± 0.76 km/h. The *maximum distance covered* is 2.56 km and the *minimum* 2.05 km while the *speed* reaches a *maximum* of 8.8 km/h and a *minimum* of 6.8 km/h.

12.3.2. The results of the technical-tactical testing, on the court, under active recovery conditions

The individual results obtained by each player are presented in Figure 12. 3. Thus, we can observe that the *average C.E.T.J.* for the whole team, after the 6 sessions of 15 minutes played after the implementation of the pedaling protocol for 15 minutes, *has a positive value of 0.12 ± 0.17 points.*

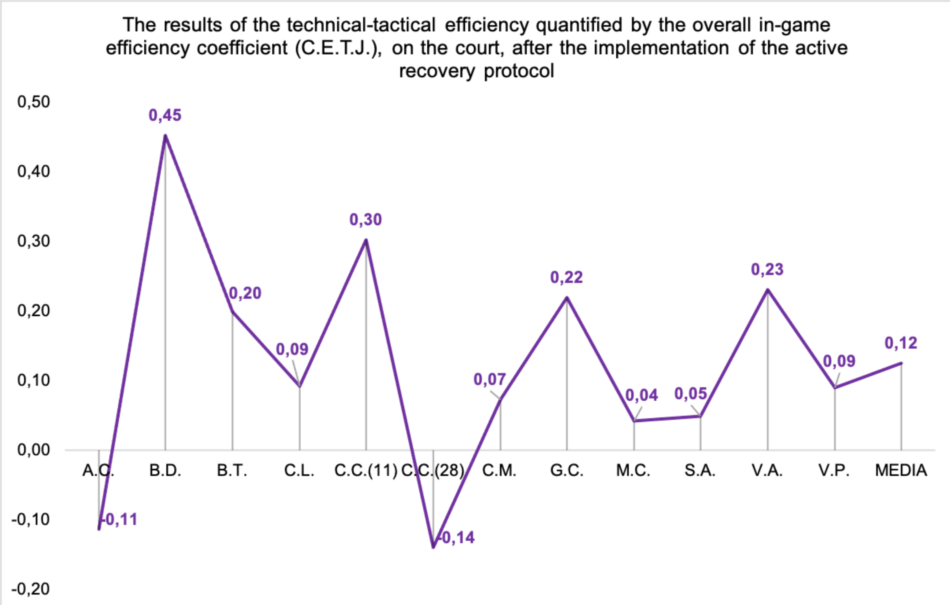


Figure 12. 3. The results of the technical-tactical efficiency quantified by the overall in-game efficiency coefficient (C.E.T.J.), on the court, after the implementation of the active recovery protocol

12.4. Comparison of the passive recovery protocol's efficiency with that of the active recovery protocol

12.4.1. Comparison of the physical evaluation protocol results

12.4.1.1. The countermovement jump - arms fixed: CMJ AF

Table 12. 3. Comparison of the jump height index (JH) values for the countermovement jump - arms fixed test (CMJ AF), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and active recovery protocols between the two tests

	t	Sig. 2-tailed	JH averages for the CMJ AF test	
			Passive recovery (N=12)	Active recovery (N=12)
JH of the CMJ AF test at the initial tests(T1)	0.18	0.863	34.57	34.73
JH of the CMJ AF test at the final tests (T2)	1.60	0.124	33.00	34.82
JH evolution of the CMJ AF test between the two tests (T2-T1)	**3.31**	**0.007**	**-1.57**	**0.09**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Analyzing the data in Table 12. 3, we find that the average evolution of *the jump height index (JH)* for the countermovement jump with arms fixed (CMJ AF) test, from the initial test to the final one, is highly significantly higher (t = 3.31, p < 0.01), with the implementation of the active recovery protocol, than with the implementation of the passive recovery protocol, between the two tests (T2-T1). **The active recovery determined a much better evolution of the JH index in the CMJ AF sample**, reflected in an average **progress** of + 0.09 cm between the two tests, compared to the **passive recovery, which determined an average decrease** of - 1.57 cm between the two tests.

Table 12. 4. Comparison of the RSI1 index values for the countermovement jump with fixed arms test (CMJ AF), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and the active recovery protocol, between the two tests

	t	Sig. 2-tailed	RSI1 average for the CMJ AF	
			Passive recovery (N=12)	Active recovery (N=12)
RSI1 of the CMJ AF test for the initial tests (T1)	0.26	0.796	0.43	0.43
RSI1 of the CMJ AF test for the final tests (T2)	**- 3.06**	**0.007**	**0.35**	**0.43**
Evolution of the RSI1 of the CMJ AF test between the two tests (T2-T1)	**- 4.35**	**0.001**	**- 0.08**	**0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

According to Table 12. 4, the average of the *RSI1 index, CMJ AF*, obtained in the final testing (T2), is highly significantly higher (t = - 3.06, p <0.01), with the implementation of the active recovery protocol before this test, than with the implementation of the passive recovery protocol. **The active recovery led to obtaining an average value of the RSI1 index of 0.43 cm/s at T2 PA, much higher compared to the passive recovery, which led to obtaining an average value of the RSI1 index of 0.35 cm / s at T2 PP.**

The evolution mean of the *RSI1 index, CMJ AF,* from the initial to the final testing, is highly significantly higher (t = - 4.35, p <0.01), with the implementation of the active recovery protocol, than with the implementation of the passive recovery protocol, between the two tests (T2-T1). **The active recovery determined a much better evolution of the RSI1 index in the AF CMJ test, reflected in an average progress of + 0.01 cm/s between the two tests, compared to the passive recovery, which determined an average decrease of - 0.08 cm/s between the two tests.**

Table 12. 5. Comparison of the peak power index (PP) values for the countermovement jump with fixed arm test (CMJ AF), obtained in the initial and final testing and the evolution of these values with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PP averages of the CMJ AF test	
			Passive recovery (N=12)	Active recovery (N=12)
PP of the CMJ AF test for the initial tests (T1)	- 0.09	0.933	2.71	2.71
PP of the CMJ AF test for the final tests (T2)	**- 2.50**	**0.023**	**2.55**	**2.72**
Evolution of the PP of the CMJ AF test between the two tests (T2-T1)	**- 3.25**	**0.008**	**- 0.16**	**0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The data in Table 12. 5, *the average of the peak jump power index (PP)*, CMJ AF, obtained in the final testing (T2), is significantly higher (t = - 2.50, p <0.05) with the implementation of the active recovery protocol before this test, than with the implementation of the passive recovery protocol**. The active recovery led to an average PP index of 2.72 w at T2 PA, much higher than for the passive recovery, which resulted in an average PP index of 2.55 w at T2 PP.**

The evolution of the peak jump power index (PP), CMJ AF, from the initial test to the final one, is highly significantly higher (t = - 3.25, p <0.01), when implementing the active recovery protocol, than with the implementation of the passive recovery, between the two tests (T2-T1). **The active recovery determined a much better evolution of the PP index in the CMJ AF test, reflected in an average progress of + 0.01 w between the two tests, compared to the passive recovery, which determined an average decrease of - 0.16 w between the two tests.**

Table 12. 6. Comparison of the peak jump velocity index (PV) values for the countermovement jump with fixed arms test (CMJ AF), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PV averages of the CMJ AF test	
			Passive recovery (N=12)	Active recovery (N=12)
PV of the CMJ AF test for the initial tests (T1)	- 1.91	0.069	2.39	2.50
PV of the CMJ AF test for the final tests (T2)	- 0.54	0.596	2.46	2.49
Evolution of the PV of the CMJ AF test between the two tests (T2-T1)	**7.24**	**0.001**	**0.06**	**- 0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Following Table 12. 6, we find that the *evolution average for the peak jump velocity index (PV)*, CMJ AF, from the initial testing to the final one, is highly significantly better (t = 7.24, p <0.01), when implementing the active recovery protocol, than with the implementation of the passive recovery protocol, between the two tests (T2-T1). **The active recovery determined a much better evolution of the PV index in the CMJ AF test, of - 0.01 m/s between the two tests, compared to the passive recovery, which determined an average increase of 0.06 m/s between the two tests.**

12.4.1.2. The squat jump - SJ

Table 12. 7. Comparison of jump height index values (JH) for the squat jump test (SJ), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	JH averages of the SJ test	
			Passive recovery (N=12)	Active recovery (N=12)
JH of the SJ test for the initial tests (T1)	- 0.01	0.992	29.99	30.00
JH of the SJ test for the final tests (T2)	- 1.01	0.325	28.50	29.90
Evolution of the JH for the SJ test between the two tests (T2-T1)	**- 4.89**	**0.001**	**- 1.49**	**- 0.11**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Analyzing the data in Table 12. 7, *the decrease average in the jump height index (JH)*, SJ, from the initial to the final testing, *is highly significantly lower* (t = - 4.89, p <0.01), when implementing the active recovery protocol, than with the implementation of the passive recovery protocol, between the two tests (T2-T1). **The active recovery resulted in a much lower regression of only - 0.11 cm between the two tests, compared to the passive recovery, which resulted in an average decrease of - 1.49 cm between the two tests.**

Table 12. 8. Comparison of the RSI1 index values for the squat jump test (SJ), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	RSI1 averages of the SJ test	
			Passive recovery (N=12)	Active recovery (N=12)
RSI1 of the SJ test for the initial tests (T1)	0.40	0.690	0.90	0.89
RSI1 of the SJ test for the final tests (T2)	**- 3.09**	**0.005**	**0.79**	**0.90**
Evolution of the RSI1 for the SJ test between the two tests (T2-T1)	**- 5.65**	**0.001**	**- 0.11**	**0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Analyzing the data in Table 12. 8, we find that *the average of the RSI1 index, SJ,* obtained in the final testing (T2), *is highly significantly higher (t = - 3.09, p <0.01*), when implementing the active recovery protocol before this test, than with the implementation of the passive recovery protocol. **The active recovery determined an average value of the RSI1 index of 0.90 cm/s at T2 PA, much higher compared to the passive recovery, which determined an average value of the RSI1 index of 0.79 cm/s at T2 PP.**

The evolution average of the RSI1 index, SJ, from the initial to the final testing, *is highly significantly higher* (t = - 5.65, p <0.01), when implementing the active recovery protocol, than with the implementation of the passive recovery protocol, between the two tests (T2-T1**). The active recovery determined an average progress of + 0.01 cm/s between the two tests, compared to the passive recovery, which determined an average decrease of - 0.11 cm/s between the two tests.**

Table 12. 9. Comparison of the peak power index (PP) values for the squat jump test (SJ), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PP averages of the SJ test	
			Passive recovery (N=12)	Active recovery (N=12)
PP of the SJ test for the initial tests (T1)	- 0.09	0.931	2.49	2.50
PP of the SJ test for the final tests (T2)	**- 2.62**	**0.015**	**2.32**	**2.51**
Evolution of the PP for the SJ test between the two tests (T2-T1)	**- 6.64**	**0.001**	**-0.18**	**0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

According to the data in Table 12. 9, *the average of the peak jump power index (PP), SJ*, obtained in the final testing (T2), *is significantly higher* (t = - 2.62, p <0.05), when implementing the active recovery protocol before this test, than with the implementation of the passive recovery protocol. **The active recovery resulted in an average PP value of 2.51 w at T2 PA, much higher compared to the passive recovery, which resulted in an average PP index of 2.32 w at T2 PP.**

The evolution average of the peak jump power index (PP), SJ, from the initial to the final test, *is highly significantly higher* (t = - 6.64, p <0.01), when implementing the active recovery protocol, than with the implementation of the passive recovery, between the two tests (T2-T1). **The active recovery determined a much better evolution of the PP index in the SJ test, reflected in an average progress of + 0.01 w between the two tests, compared to the passive recovery, which determined an average decrease of - 0.18 w between the two tests.**

Table 12. 10. Comparison of the peak jump velocity index (PV) values for the squat jump test (SJ), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PV averages of the SJ test	
			Passive recovery (N=12)	Active recovery (N=12)
PV of the SJ test for the initial tests (T1)	- 0.09	0.931	2.31	2.32
PV of the SJ test for the final tests (T2)	- 1.87	0.075	2.40	2.48
Evolution of the PV for the SJ test between the two tests (T2-T1)	**4.72**	**0.001**	**0.10**	**0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Table 12. 10, contains data according to *which the evolution average of the peak jump velocity index (PV), SJ*, from the initial testing to the final one, *is highly significantly better* (t = 7.24, p <0.01), with the implementation of the active recovery protocol, than when implementing the passive recovery, between the two tests (T2-T1). **The active recovery determined a much better evolution of the PV index in the SJ test, reflected in an average increase of only 0.01 m/s between the two tests, compared to the passive recovery, which determined an average increase of 0.10 m/s between the two tests.**

12.4.1.3. The medicine ball right/left side throw (AMMD/AMMS)

Table 12. 11. Comparison of the peak throwing power index (PP) values of the medicine ball right hand throw (AMMD), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PP averages of the AMMD test	
			Passive recovery (N=12)	Active recovery (N=12)
PP of the AMMD test for the initial tests (T1)	0.01	0.998	10.59	10.59
PP of the AMMD test for the final tests (T2)	- 0.39	0.699	9.97	10.56
Evolution of the PP for the AMMD test between the two tests (T2-T1)	**- 2.18**	**0.041**	**- 0.62**	**- 0.03**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

According to Table 12. 11, *the decrease average in the peak throwing power index (PP), AMMD,* from initial to final testing, *is significantly lower* (t = - 2.18, p <0.05), when implementing the active recovery protocol, than with the implementation of the passive recovery protocol between the two tests (T2-T1). **The active recovery resulted in a much better evolution of the PP index in the AMMD test, reflected in an average decrease of only - 0.03 w between the two tests, compared to the passive recovery, which determined an average decrease of - 0.62 w between the two tests.**

Table 12. 12. Comparison of the peak throwing velocity index (PV) values for the medicine ball right hand throw (AMMD), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PV averages of the AMMD test	
			Passive recovery (N=12)	Active recovery (N=12)
PV of the AMMD test for the initial tests (T1)	- 0.76	0.457	6.77	7.23
PV of the AMMD test for the final tests (T2)	- 0.60	0.556	6.83	7.20

Evolution of the PV for the AMMD test between the two tests (T2-T1)	0.40	0.700	0.60	- 0.03

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Analyzing the data in Table 12. 12, **we find that there are no significant differences in the values of the peak throwing velocity (PV) index for the medicine ball right hand throw test (AMMD).**

Table 12. 13. Comparison of the peak throwing power index (PP) values for the medicine ball left hand throw (AMMS), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocol between the two tests

	t	Sig. 2-tailed	PP averages of the AMMS test	
			Passive recovery (N=12)	Active recovery (N=12)
PP of the AMMS test for the initial tests (T1)	- 0.01	0.999	9.63	9.63
PP of the AMMS test for the final tests (T2)	- 1.22	0.234	8.36	9.57
Evolution of the PP for the AMMS test between the two tests (T2-T1)	**- 4.28**	**0.001**	**-1.27**	**- 0.06**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

In Table 12. 13, *the decrease average in the peak throwing power index (PP), AMMS,* from initial to final testing, *is highly significantly lower* ($t = -4.28$, $p < 0.01$), when implementing the active recovery protocol, than with the implementation of the passive recovery, between the two tests (T2-T1). **The active recovery resulted in a much better evolution of the PP index in the AMMS test, reflected in an average decrease of only - 0.06 w between the two tests, compared to the passive recovery, which determined an average decrease of - 1.27 w between the two test sets.**

Table 12. 14. Comparison of the of the peak throwing velocity index (PV) values for the medicine ball left hand throw (AMMS), obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery and the active recovery protocols between the two tests

	t	Sig. 2-tailed	PV averages of the AMMS test	
			Passive recovery (N=12)	Active recovery (N=12)
PV of the AMMS test for the initial tests (T1)	- 1.71	0.101	6.15	7.13
PV of the AMMS test for the final tests (T2)	- 0.66	0.514	6.69	7.08
Evolution of the PV for the AMMS test between the two tests (T2-T1)	**2.70**	**0.021**	**0.55**	**- 0.04**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The evolution average of the peak throw velocity index (PV), AMMS, from the initial to the final testing, *is significantly better* ($t = 2.70$, $p < 0.05$), when implementing the active recovery protocol, than with the implementation of the passive recovery, between the two tests (T2-T1). **The active recovery resulted in a much better evolution of PV in the AMMS test, reflected in an average decrease of - 0.04 m/s between the two tests, compared to the passive recovery, which determined an average increase of 0.55 m/s between the two tests** (Table 12. 14**).**

12.4.1.4. The 10-meter acceleration test

Table 12. 15. Comparison of the 10 m acceleration test values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and of the active recovery protocol, between the two tests

	t	Sig. 2-tailed	10 m acceleration test averages	
			Passive recovery (N=12)	Active recovery (N=12)
10 m acceleration test values at initial tests (T1)	- 0.11	0.918	2.14	2.14
10 m acceleration test values at the final tests (T2)	1.39	0.178	2.19	2.13
Evolution of values in the 10m acceleration test between the two tests (T2-T1)	**9.61**	**0.001**	**0.05**	**- 0.01**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

According to Table 12. 15, *the evolution of the values in the 10m acceleration test*, from the initial to the final testing, *is highly significantly better* (t = 9.61, p <0.01), with the implementation of the active recovery protocol, than in the case of the passive recovery protocol implementation, between the two tests (T2-T1). **The active recovery resulted in a much better evolution of the 10 m acceleration test values, reflected in an average decrease of - 0.01 s between the two tests, compared to the passive recovery, which determined an average increase of 0.05 s between the two tests.**

12.4.2. Comparison of the physiological evaluation protocol results

Table 12. 16. Comparison of the heart rate (FC) physiological index values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and the active recovery protocol, between the two tests

	t	Sig. 2-tailed	FC averages	
			Passive recovery (N=12)	Active recovery (N=12)
FC values at initial tests (T1)	- 0.60	0.558	121.75	123.50
FC at the final tests (T2)	**- 8.37**	**0.001**	**87.58**	**105.90**
Evolution of the FC values between the two tests (T2-T1)	**- 4.51**	**0.001**	**- 34.17**	**- 17.60**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The data in Table 12. 16, demonstrate that in the final testing (T2), *the average heart rate (FC) is highly significantly higher (t = - 8.37, p <0.01), with the implementation of the active recovery protocol before this test, than in the case of the passive recovery protocol.* **The active recovery resulted in an average FC index of 105.90 ppm at T2 PA, much higher than the passive recovery, which resulted in an average FC index of 87.58 ppm at T2 PP.**

The decrease average in heart rate (FC) from initial to final testing is highly significantly lower (t = -4.51, p <0.01) when using the active recovery protocol than when applying the passive recovery protocol, between the two tests (T2-T1). ***The active recovery resulted in a much better evolution of the FC index, reflected in an average decrease of - 17.60 ppm between the two tests, maintaining its value at an optimal level of 105.9 ppm, compared to the passive recovery, which determined an average decrease. of - 34.17 ppm between the two tests.***

Table 12. 17. Comparison of the of lactic acid (AL) physiological index values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and of the active recovery protocol, between the two tests

	t	Sig. 2-tailed	AL averages	
			Passive recovery (N=12)	Active recovery (N=12)
AL values at initial tests (T1)	0.14	0.893	1.72	1.69
AL at the final tests (T2)	**4.31**	**0.001**	**1.57**	**2.48**
Evolution of the AL values between the two tests (T2-T1)	**- 6.93**	**0.001**	**- 0.15**	**0.79**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The average lactic acid (AL) index, obtained in the final testing (T2), *is highly significantly higher (t = 4.31, p <0.01),* with the implementation of the active recovery protocol before this test, than in case of the passive recovery protocol implementation. **The active recovery resulted in an average AL value of 2.48 mmol/L at T2 PA, much higher compared to the passive recovery, which resulted in an average AL index of 1.57 mmol/L at T2 PP.**

The evolution average of the lactic acid (AL) index, from the initial to the final testing, *is highly significantly higher (t = - 6.93, p <0.01*), with the implementation of the active recovery protocol, than in case of the passive recovery protocol implementation between the two tests (T2-T1). **The active recovery determined an evolution of the AL index, reflected in an average increase of 0.79 mmol/L between the two tests, compared to the passive recovery, which determined an average decrease of - 0.15 mmol/L between the two tests.**

Table 12. 18. Comparison of the serum glucose (G) physiological index values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and the active recovery protocol, between the two tests

	t	Sig. 2-tailed	G averages	
			Passive recovery (N=12)	Active recovery (N=12)
G values at initial tests (T1)	0.11	0.916	89.58	89.42
G at the final tests (T2)	**- 4.13**	**0.001**	**88.17**	**94.50**
Evolution of the G values between the two tests (T2-T1)	**- 3.48**	**0.002**	**-1.42**	**5.08**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The value of serum blood glucose (G), obtained at the final test (T2), *is highly significantly higher* (t = - 4.13, p. <0.01), with the implementation of the active recovery protocol, than in case of the passive recovery protocol implementation. **The active recovery resulted in an average G index of 94.50 mg/dL at T2 PA, much higher compared to the passive recovery, which resulted in an average G index of 88.17 mg/dL at T2 PP.**

The evolution average of the serum glucose (G) physiological index, from the initial to the final test, *is highly significantly higher (t = - 3.48, p <0.01),* with the implementation of the active recovery protocol, than in case of the passive recovery protocol implementation between the two tests (T2-T1). **The active recovery resulted in a much better evolution of the G index, reflected in an average increase of 5.08 mg/dL between the two tests, compared to the passive recovery, which resulted in an average decrease of - 1.42 mg/dL between the two tests.**

Table 12. 19. Comparison of the body temperature (Tc) physiological index values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and of the active recovery protocol, between the two tests

	t	Sig. 2-tailed	T_c averages	
			Passive recovery (N=12)	Active recovery (N=12)
T_c values at initial tests (T1)	- 0.24	0.811	37.73	37.75
T_c at the final tests (T2)	**- 10.64**	**0.001**	**36.09**	**37.37**
Evolution of the T_c values between the two tests (T2-T1)	**- 9.95**	**0.001**	**- 1.63**	**- 0.38**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

The average body temperature (Tc), obtained in the final testing (T2), *is highly significantly higher* (t = - 10.64, p <0.01), with the implementation of the active recovery protocol before this test, than in case of the passive recovery protocol implementation. **The active recovery determined an average value of the T_c index of 37.37°C at T2 PA, much higher when compared to the passive recovery, which determined an average value of the T_c index of 36.09°C at T2 PP.**

The decrease average in the body temperature (T_c) physiological index, from the initial to the final testing, *is highly significantly lower* (t = - 9.95, p <0.01), with the implementation of the active recovery protocol, than in case of the passive recovery protocol implementation between the two tests (T2-T1). **The active recovery resulted in a much better evolution of the T_c index, reflected in an average decrease of - 0.38°C between the two tests, maintaining its value at an optimal level of 37.4°C, when compared to the passive recovery, which determined an average decrease of - 1.63°C between the two tests.**

Table 12. 20. Comparison of the oxygen saturation in the blood (S O2) physiological index values, obtained in the initial and final testing and the evolution of these values, with the implementation of the passive recovery protocol and the active recovery protocol, between the two tests

	t	Sig. 2-tailed	S O_2 averages	
			Passive recovery (N=12)	Active recovery (N=12)
S O_2 values at initial tests (T1)	0.80	0.430	98.67	98.50
S O_2 at the final tests (T2)	0.00	1.000	98.75	98.75
Evolution of the S O_2 values between the two tests (T2-T1)	- 1.08	0.296	0.08	0.25

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Regarding the *oxygen saturation in the blood (S O_2), physiological index, there are no significant differences* from the values obtained in the initial testing (T1), performed before the implementation of passive recovery or active recovery protocols. **Nor are there statistically significant differences in the evolution of the oxygen saturation in the blood physiological index**, from the initial to the final testing (T2-T1), with the implementation of the passive recovery protocol or active recovery between them.

12.4.3. Comparison of the on-court evaluation protocol results

Table 12. 21. Comparison of the motor and technical-tactical on-court evaluation test values, measured after the implementation of the passive recovery protocol and the active recovery protocol

	t	Sig. 2-tailed	Averages of on-court assessment tests	
			Passive recovery (N=12)	Active recovery (N=12)
Average distance covered	**- 4.30**	**0.001**	**1.99**	**2.25**
Average speed	- 0.53	0.599	7.62	7.78
Overall efficiency coefficient in the game (C.E.T.J.)	**- 4.71**	**0.001**	**- 0.22**	**0.12**

Legend: t = value of t; sig. (2-tailed) = significance level of t, which must be less than 0.05 for the differences between PP and PA to be statistically significant

Analyzing the data in Table 12. 21, **we find that there are significant differences in the performance of the subjects following the implementation of the passive recovery and the active recovery protocol**, in two of the three on-court assessment tests, expressed in average values, after 6 training matches, namely: **the average distance covered** and **the overall efficiency coefficient in the game (C.E.T.J.)**. These differences are shown graphically in the figures below.

The average distance covered on the court, measured with the Garmin Fenix 5S watch, *is highly significantly higher* (t = - 4.30, p <0.01) when applying the active recovery protocol than when applying the passive recovery protocol. **The active recovery resulted in an average value of the distance covered on the court of 2.25 km, much higher when compared to the average value obtained after the passive recovery, of 1.99 km (Figure 12. 4).**

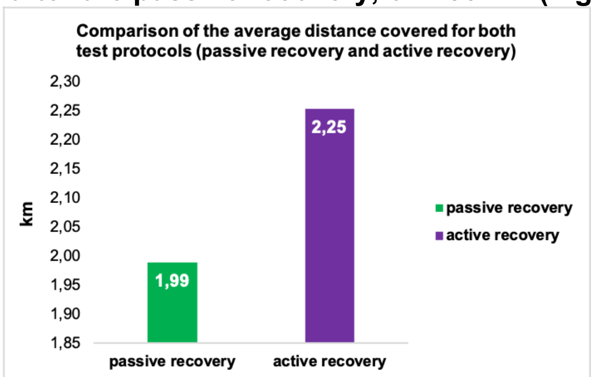


Figure 12. 4. Comparison of the average distance covered for both test protocols (passive recovery and active recovery)

The average of the overall efficiency coefficient in the game (C.E.T.J.) is highly significantly higher (t = - 4.71, p <0.01), with the implementation of the active recovery protocol, than with the passive recovery protocol implementation. **The active recovery resulted in an average value of the overall efficiency coefficient in the game of 0.12, much higher when compared to the average value of this coefficient, obtained after the passive recovery, of – 0.22 (**Figure 12. 5**).**

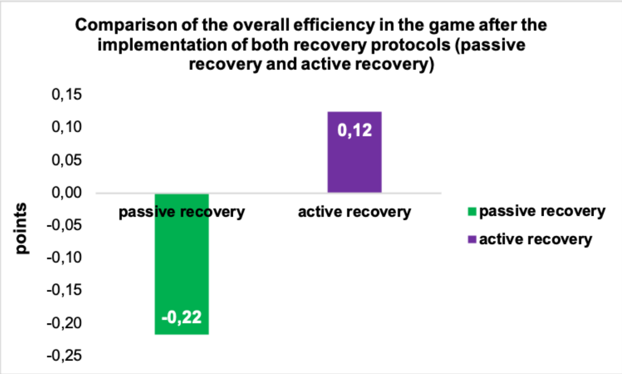


Figure 12. 5. Comparison of the overall efficiency in the game after the implementation of both recovery protocols (passive recovery and active recovery)

Based on the analyzed data, we can conclude that the active recovery protocol, consisting of 15 minutes of warm up at an effort intensity of 60% of FC_{max} is much more efficient when compared to the passive recovery, consisting of 15 minutes of complete inactivity, in seated position on the bench, since it maintains the players' optimal physiological level of training and it improves their physical performance, motor performance and technical-tactical efficiency on the court.

12.5. Analysis of the correlations resulting from the evaluations in the primary experimental research

12.5.1. Correlations between changes in the performance of players on the court, after the implementation of the active recovery protocol

The **hypothesis** tested in the primary research is that maintaining or attenuating the decrease in the body's level of readiness for effort through the active recovery implemented on the edge of the court, leads to an increase in the performance of handball players in matches, when they enter the court from the substitute position.

Table 12. 22. Correlations between changes in court performance, recorded after the implementation of the active recovery protocol

		1	2	3
1	Modification of the distance covered on the court			
2	Modification of the movement speed	0.41		
3	Modification of the overall efficiency coefficient in the game	***0.83*****	0.09	

***** The correlation is significant at a threshold of significance of 0.01 (2-tailed).***

According to the Pearson correlation coefficient presented in Table 12. 22 there are links between the analyzed variables and we can observe a significant positive correlation *(r = 0.83, p <0.01)*, between the change in the distance covered and the change in the overall efficiency coefficient in the game. This means that the players who recorded the largest differences between the distance covered after the passive recovery and the distance covered after the active recovery also obtained the largest increases in technical-tactical efficiency on the court.

12.5.2. Correlations between the changes in the coefficients measured for the quantification of the technical-tactical efficiency on the court, after the implementation of the active recovery protocol

Table 12. 23. Correlations between the change in the values of the coefficients calculated for the quantification of the technical-tactical efficiency of the players, after the implementation of the active recovery protocol

		1	2	3	4
1	The increase in the global efficiency coefficient (C.G.E.)				
2	The increase in the coefficient of standardized successful actions in the game (C.Ap.S.J.)	-0.18			
3	The decrease in the standardized error coefficient in the game (C.G.S.J.)	-0.1	-0.05		
4	The increase in the overall efficiency coefficient in the game (C.E.T.J.)	*0.59**	*0.55**	*-0.55**	

** The correlation is significant at a threshold of significance of 0.05 (2-tailed).*

The Pearson correlation analysis, from Table 12. 23 describes *a statistically significant positive relationship (r = -0.59, p <0.05)* between the global efficiency coefficient (C.G.E.) and the overall in-game efficiency coefficient (C.E.T.J.), **which means that through the protocol to maintain the level of preparation of the body for effort, the players have improved their technical-tactical performance on the court and their efficiency in solving the standardized technical-tactical actions in the game is related to the overall efficiency quantified at the end of the matches. In addition, there is a clear correlation between the standardized successful action coefficient in the game and the C.E.T.J. *(r = -0.55, p> 0.05)*, as well as a negative correlation between the standardized error coefficient in the game and the C.E.T.J. *(r = -0.55, p> 0.05)*, but these associations are not statistically significant.**

12.6. Conclusions of the primary experimental research

The primary experimental research was conducted as a result of identifying the necessity to replace the passive recovery on the edge of the handball court, on the basis of both the opinion of specialists in the field and the results of our preliminary research. We considered that the implementation of an active recovery program established at a correct intensity of the effort will help maintain an optimal level of body's preparation for effort and in this way will contribute to increase the efficiency of the players on the court, when they are introduced in the match, as substitutes.

Regarding the results of the **physical evaluation** obtained in the jump tests, in conditions of active recovery, the conclusions are the following:

- ✓ Through the active recovery, the players managed to maintain the values of all performances in the jumping tests, from the initial test, T1 PA (testing immediately after the match warm-up), to the final one, T2 PA (testing after 15 minutes of active recovery).
- ✓ Compared to the **passive** recovery, the **active** recovery resulted in a much better evolution of all the indices specific to the jump tests, a fact demonstrated by the analysis of the results obtained in the *final tests and the evolution between the initial and final testing*. This *confirms the effectiveness of this newly implemented active recovery protocol in maintaining the physical performance of the players between the two tests.*

These results reveal the effectiveness of the active recovery protocol implemented in the case of the handball players and confirm the specific hypothesis H 1.1. of the primary experimental research for jump tests (CMJ AF, SJ).

Regarding the results of the **physical evaluation** obtained in the medicine ball side throw test, on the right (AMMD) and on the left (AMMS), in conditions of active recovery, we can state the following:

- ✓ Statistical analysis indicates that there are **no significant differences** in the physical performance of the subjects when applying the active recovery protocol between initial and final testing, for either of the 2 indices of the medicine ball right-handed (AMMD) and left handed (AMMS) throwing tests.
- ✓ After comparing the efficiency of the active recovery protocol with that of the passive recovery protocol by analyzing the results obtained in the *final tests and the evolution between the initial and final testing,* we can say that the **active** recovery determined a much better evolution of the indicators specific to the AMMD and AMMS tests, which confirms the effectiveness of this newly implemented active recovery protocol in mitigating the reduction of players' physical performance between the two tests.

These results reveal the effectiveness of the active recovery protocol implemented in the case of the handball players and confirm the specific hypothesis H 1.1. of the primary experimental research for the medicine ball right side (AMMD) and the left side (AMMS) throwing tests.

Regarding the results of the **physical evaluation** obtained in the 10-meter acceleration test, in conditions of active recovery, we can state the following:

- ✓ The active recovery resulted in a much better evolution of the 10 m acceleration test values, reflected in an average decrease of - 0.01 s between the two tests, compared to the passive recovery, which determined an average increase of 0.05 s between the two tests.

The results obtained by the players after the 10 m acceleration test confirm the effectiveness of the active recovery protocol, thus, the specific hypothesis H 1.1. of the primary experimental research is accepted in this case as well.

Regarding the results of the **physiological evaluation** obtained in the case of the heart rate (FC) index, investigated under active recovery conditions, the conclusions are as follows:

- ✓ The analysis of the **heart rate** index (FC) records an average value of 123.5 ppm at the initial test (T1 PA), with a coefficient of variation of 6.6%, within the **high homogeneity** threshold. After implementation of the active recovery protocol, at the final testing (T2 PA) the FC value decreased by 17.6 ppm (105.9 ppm) compared to the initial testing, but it should be remembered that these results were followed and determined directly by our methodological intervention.
- ✓ After comparing the efficiency of the active recovery protocol with that of the passive recovery protocol by analyzing the results obtained in the *final tests and the evolution between the initial and final tests*, in the case of FC, we identified statistically significant differences both in terms of the **heart rate physiological index values, obtained in the final testing (T2)**, performed after the implementation of the passive recovery or active recovery protocol, as well as regarding **the evolution of this index, from the initial to the final test (T2-T1)**, with the implementation of the 2 recovery protocols between them.
  - During the 15 minutes of cycling, the use of modern technological devices helped maintain physical activity at 60% FC_{max}, which was also the percentage of effort intensity we pursued. The active recovery resulted in an average FC value of 105.9 ppm at T2 PA, much higher compared to the passive recovery, which resulted in an average FC index of 87.58 ppm at T2 PP. Although the average heart rate (FC) physiological index is highly significantly lower (t = 8.83, p. <.01) at the final testing, compared to the initial one, the decrease is one controlled by our direct intervention in research.

The specific hypothesis H 1.2. is confirmed in what regards the efficiency of the correct monitoring of the effort parameters, by using the technological devices, according to the individual particularities of the players.

Regarding the results of the **physiological evaluation**, obtained by the players in the analysis of the biochemical parameters, in conditions of active recovery, we can state the following:

- ✓ After the pedaling program applied during the active recovery, the level of **capillary lactate (AL) increased** from an average value of 1.69 mmol/L (T1 PA) to 2.48 mmol/L (T2 PA) and it is highly significantly higher = - 3.37, p. <0.01) at the final testing, when compared to the initial one. **The active recovery implemented between the two tests determined, on average, the increase of the capillary lactate values of the subjects.**
- ✓ After comparing the efficiency of the active recovery protocol with that of the passive recovery protocol, we identified statistically significant differences both in terms of the **lactic acid physiological index values**, obtained in the final tests (T2), performed after the implementation of the passive recovery or active recovery protocol, as well as regarding the **evolution of this index, from the initial to the final testing (T2-T1)**, when implementing the 2 recovery protocols between them. The active recovery resulted in an average AL index value of 2.48 mmol/L at T2 PA, much higher compared to the passive recovery, which resulted in an average AL index value of 1.57 mmol/L at T2 PP (t = 4.31, p <0.01). The active recovery resulted in a much higher evolution of the AL index, reflected in an average increase of 0.79 mmol/L between the two tests, compared to the passive recovery, which resulted in an average decrease of -0.15 mmol/L between the two tests (t = - 6.93, p <0.01).

The results obtained by the players following this investigation do not confirm the specific hypothesis H 1.3., however, lactate values correspond to the aerobic/anaerobic threshold and thus confirm the specific hypothesis H 1.4. of the primary experimental research.

- ✓ The active recovery resulted in an average G index of 94.50 mg/dL at T2 PA, much higher than for the passive recovery, which resulted in an average G index of 88.17 mg/dL at T2 PP (t = - 4.13, pp. <0.01). *This indicates that the impact of physical exertion on the players' bodies during the active recovery did not lead to fatigue*.

Results obtained by the players following this investigation, confirm the specific hypothesis H 1.4. of the primary experimental research.

Investigations of the **body temperature** (T_c) physiological index allow us to draw the following conclusions:

- ✓ Following the pedaling program applied within the active recovery protocol, at an effort intensity of 60%, the average of the body temperature (T_c) physiological index is highly significantly lower (t = 2.89, p <0.01) in the final testing, when compared to the initial one. The active recovery implemented between the two tests determined, on average, the decrease in the players' body temperature values.
- ✓ After comparing the efficiency of the active recovery protocol with that of the passive recovery protocol by analyzing the results obtained in *the final tests and the evolution between the initial and final tests*, in the case of T_c, statistically significant differences both in terms of **the body temperature physiological index values obtained in the final tests (T2)**, performed after the implementation of the passive recovery or active recovery protocol, as well as regarding **the evolution of this index, from the initial test to the final test (T2-T1),** with the implementation of the 2 recovery protocols between them. **The active recovery resulted in an average value of the T_c index of 37.37°C at T2 PA, much higher when compared to the passive recovery, which resulted in an average value of the T_c index of 36.09°C at T2 PP (t = - 10.64, p <0.01)**. The active recovery resulted in a much better evolution of the T_c index, reflected in an average decrease of - 0.38°C between the two tests, maintaining its value at an optimal level of 37.4°C, when compared to the passive recovery, which determined an average decrease of - 1.63°C between the two tests (t = - 9.95, p <0.01). This confirms the positive influence of the active recovery protocol on the attenuation of the decrease in body temperature by the time of the final testing.
  The results obtained by the players following this investigation, confirm the specific hypothesis H 1.5. of the primary experimental research, according to which, unlike the inactivity specific to the passive recovery, the optimization of the effort level during the active recovery by setting the effort intensity at 60% of the maximum aerobic potential, determines the maintenance or the attenuation of the decrease in body temperature values recorded after the standard match warm up.
- ✓ The values recorded for blood **oxygen saturation** show a **slight increase** from an average concentration of 98.50% after T1 PA and 98.75% after T2 PA. In this case, there were no statistically significant differences (t = 1.25, p = 0.223> 0.05). This index is the only one that did not show statistically significant differences in any of the comparative statistical analyses performed between the two types of recovery implemented in our research. **Blood oxygen saturation results support specific hypothesis H 1.4.**

According to the data obtained in the **on-court assessment**, after recording the motor performance, the conclusions are the following:

- ✓ Following the comparison of the efficiency of the active recovery protocol with that of the passive recovery protocol, in the case of on-court motor performance, we identified statistically significant differences **in the case of the total distance covered**. The active recovery resulted in an average distance of 2.25 ± 0.16 km at T2 PA, much higher when compared to the passive recovery, which resulted in an average value of 1.99 ± 0.14 km at T2 PP. Thus, the average distance covered on the court is highly significantly higher (t = - 4.30, p = 0.001, <0.01), in the case of the implementation of the active recovery protocol, than in the case of the implementation of the passive recovery protocol. **This, the specific hypothesis H 1.6. is confirmed** in terms of an increase in **running distances**.
- ✓ Following the comparison of the efficiency of the active recovery protocol with that of the passive recovery protocol, in the case of the motor performance on the court, we identified positive evolutions of the **running speed**. Although the active recovery resulted in an average value of 7.78 ± 0.76 km/h at T2 PA, which is higher than the passive recovery, which resulted in an average value of 7.62 ± 0.77 km/h at T2 PP, these results are not statistically significant (t = -0.53, p = 0.599> 0.05) and, thus, **the specific hypothesis H 1.6 is not confirmed in the case of running speed**.

According to the data obtained from the **on-court evaluation**, after recording the technical-tactical efficiency, the conclusions are the following:

- ✓ **The average overall efficiency coefficient in the game (C.E.T.J.)** for the whole team, after the 6 sessions of 15 minutes played after the implementation of the bicycle pedaling protocol for 15 minutes, has a positive value of 0.12 ± 0.17 points and varies between a minimum of efficiency of -0.14 points obtained by the substitute player from the right wing position and the maximum value of C.E.T.J. which is 0.45 points, being obtained by the titular player from the center position;
- ✓ Following the statistical comparison of the active recovery protocol with that of the passive recovery protocol efficiency, in the case of the technical-tactical efficiency of the players, we can state that **the active recovery determined an average value of the overall efficiency coefficient in the game of 0.12 points, much higher when compared to the average value of this coefficient, obtained after the passive recovery, of - 0.22 points.**

Thus, the specific hypothesis H 1.7. is confirmed, according to which, when compared to the specific inactivity of the passive recovery, maintaining the effort capacity at 60% of the maximum individual potential, by using the active recovery protocol on the edge of the handball court, determines the increase of the handball players' technical-tactical efficiency on the court.

Through the newly implemented protocol to maintain the body's level of preparation for effort, the players have improved their technical-tactical performance on the court and their efficiency in solving standardized technical-tactical actions in the game is related to the overall quantified efficiency at the end of matches.

In addition, through the active recovery protocol, we identified an increase in the coefficient of successful actions (C.Ap.S.J.) concurrently with a decrease in the coefficient of standardized errors in the game of handball (C.G.S.J.). The analysis of the correlations between the change in the values of these coefficients after the implementation of the active recovery, identified the existence of a positive connection between the increase of C.Ap.S.J. and C.E.T.J. (r = -0.55, p> 0.05), as well as a negative association between C.G.S.J. and C.E.T.J. (r = -0.55, p> 0.05).

The general conclusion of the primary experimental research is that, based on the confirmation of all specific hypotheses (except the one concerning running speed), *the effectiveness of the newly implemented active recovery protocol is confirmed in maintaining the physical performance of the players between the two tests, by comparison with the adverse effects caused by the inactivity specific to the passive recovery.*

Based on the analyzed data, **the main hypothesis of the research is accepted**, according to which: *The motor performance and the technical-tactical efficiency on the court, of the substitute handball players, can be improved by replacing the inactivity on the edge of the court with an active recovery protocol, which involves pedaling stationary bicycles at an intensity of 60% of the FC_{max} and which thus contributes to maintaining or mitigating the decrease in the physical and physiological benefits brought to the body by the standard match warm up.*

CHAPTER 13. GENERAL CONCLUSIONS AND PROPOSALS

13.1. Theoretical conclusions

The theoretical substantiation of this paper was made in accordance with the multidisciplinary aspect of the chosen topic and it cumulates a significant amount of information on the factors influencing sports performance and performance models, game trends and physical, physiological and technical-tactical demands imposed by the current handball competitions, on the role of technology in the process of measuring and evaluating effort capacity and sports performance.

The **theoretical originality** of the paper lies in the fact that it highlights a new approach to the organization of time on the edge of the handball court by implementing an active recovery protocol that includes methods and means of warming up the body for effort, which significantly contributes to mitigating the negative effects of complete inactivity on substitute benches. The data provided refer to the use of objective methods and means of assessing the physical and technical-tactical potential of athletes, male and female, having applicability in all team sports, at all age levels.

The cumulative individual record sheets provide the possibility to note all the standardized actions during a match and the calculation tables for all the coefficients are necessary to determine all the variables necessary for the calculation formula of the overall efficiency coefficient in the game (C.E.T.J.). In this way, any coach can determine for each player, the degree of strain and utility of each standardized technical-tactical action in the sport practiced, as well as the importance of positive actions and the severity of errors made, all related to playing time.

The calculation formula of C.E.T.J. must be adapted by each coach to the physical potential of his players (by determining the coefficient of strain based on individual heart rate), to the standardized actions in his team's game and their utility (by determining the total number of standardized technical-tactical actions and assigning values), to the standardized positive actions in his team's game (by determining the total number of standardized positive actions and assigning values) and to standardized errors in his team's game (by determining the total number of standardized errors and assigning values). The last step that completes the process of lending objectivity to the evaluation is to relate all these actions to the athletes' total playing time.

13.2. Methodological conclusions

Due to the technological advance, which has provided portable measuring instruments, the exploratory methodology of this paper addresses more effectively the physical and functional state of the body.

<u>Regarding the research methodology, we can draw the following conclusions:</u>

1) Monitoring the effort on bicycles with the help of modern technology contributed to maintaining the effort parameters (heart rate, power, cadence and pedaling speed), at the aimed for intensity, during the entire active recovery program.
2) The content of the standard match warm-up program remained unchanged throughout the experimental research. The comparison of the results obtained in the initial tests (after warm up) does not show significant differences, which certifies the correct organization and completion of the standard match warm-up program, the effects on the body's level of preparation for effort being similar, both in preliminary research and in the primary one.
3) In addition to the FC monitoring, we considered that during pedaling it is necessary to follow and observe the external effort parameters that refer to the pedaling power, cadence, and speed. For this reason, during the training to familiarize the players with stationary bikes, we identified the values that needed to be reached and maintained for all these parameters, so that the heart rate may correspond to a percentage of 60% of the maximum aerobic potential (FC_{max}).
4) 4) The intensity of the effort during the standard warm-up for the match remained constant throughout all our interventions and, according to the scale of effort intensity, proposed by Harre (1982) quoted by Bompa (2002, p. 67), it fell into the category of intermediate efforts (69% of FC_{max}). If, after 15 minutes of passive recovery, the level of effort decreased to 49% FC_{max}, through the active recovery, we managed to maintain it at 60% FC_{max}, the reduction

of heart rate being a controlled and directed action, so as for it not to fall below the threshold of intermediate efforts (50-70% FC_{max}).

5) Vertical jumps have been accepted as valid methods for assessing neuromuscular function/ maximum anaerobic power in the lower limbs (Markovic et al., 2004). Power is seen as the most important attribute in most sports and it is defined as the amount of work done in a unit of time (Tudor, V., 2005, p. 111).
6) Monitoring lactacidemia allowed us to assess the adaptive metabolic changes induced by the effort specific to the active recovery and certified the correct choice of exercise intensity that corresponded to slightly higher lactate values above baseline (2.48 mmol/l), corresponding to the aerobic/anaerobic threshold (4 mmol/l). This aspect indicates both the optimal use of the effort intensity and a very good level of physical training for the players subjected to our research that occasioned a low synthesis of the capillary lactate.

13.3. Conclusions drawn from the experimental research

1) The information base obtained from the opinion questionnaire, doubled by the results obtained in the preliminary experimental research, determined the identification of the necessity to replace the passive recovery with an active recovery protocol on the edge of the court during handball matches, especially designed for substitute players.
2) *The explanation for the handball players' decrease in physical performance in jumping tests after the passive recovery can be associated with a significant, concurrent decrease in the body temperature physiological index, while the values obtained after the implementation of the active recovery can be the result of attenuating the decrease in the T_c index.*
3) 3) In contrast to the negative consequences of the passive recovery, the effectiveness of the newly implemented active recovery protocol is reflected in maintaining or mitigating the decrease in all physical indices specific to jump tests (CMJ AF and SJ), medicine ball throwing tests (AMMD and AMMS) or to those concerning acceleration speed (10 m acceleration test).
4) Maintaining the intensity of the pedaling effort at 60% of the maximum aerobic potential caused an **increase** in the level of **lactic acid** in the blood, when compared to that identified immediately after match the warm-up, but **the values obtained at the end of the active recovery program do not indicate a surpassing of the anaerobic threshold, of 4 mmol/l**. Such a situation would have meant that the players would have been subjected to exhausting efforts. The mean values of 2.48 ± 0.7 mmol/l identified by the analysis of blood samples after 15 minutes of cycling, confirm the information provided by the specialized literature and certify the correct use of effort intensity at 60% of maximum aerobic potential in our primary experiment.
5) **The passive recovery** resulted in a significant decrease in T_c values, by 4% below the initial level attained, reaching an average value of 36.09°C. According to the studies, the reduction of temperature by one degree Celsius causes a decrease in performance by 3% (Sargeant, 1987), a fact supported and demonstrated by the results identified especially in the jumping tests. Our results are consistent with those obtained in other studies on basketball and football, that have identified a strong correlation between decreased body temperature and decreased athletic performance in jumping and speed tests (Galazoulas, 2012; Mohr et al., 2004). **The active recovery**, although it caused a significant decrease in T_c values, from a value of 37.75°C to 37.37°C, the regression is of only 1.01%, and in this case the physical performance connected to jumps was maintained.
7) Both for the technical-tactical actions in the offensive phase and for the positive ones or for standardized errors in the game, the coach is the one who appreciates the utility of one action against another, by comparing them successively, in pairs, using matrix tables. In other words, we can state that this process reflects the technical-tactical strategy of the team, as it is designed by the coach. The major advantage in this case is making the players aware of the demands and requirements of each coach in connection to their evolution on the court.
8) *The most important aspect revealed by the primary experimental research is that the active recovery has led to an increase in the players' motor performance and technical-tactical efficiency, since it maintained the physical and physiological indices at values similar to*

those obtained after the standard match warm up. Although the coefficient of overall efficiency in the game (C.E.T.J.) has improved following the implementation of the active recovery protocol, we must keep in mind that the technical-tactical efficiency is also influenced by other factors besides the body's level of preparation for effort before entering the court, among the most important being the individual technical-tactical level and the relations among teammates in the game.

Based on the analyzed data, we can conclude that the passive recovery protocol, implemented after the initial testing performed immediately after the match warm-up (T1 PP), diminishes the players' performance and the optimal level of preparation for the effort specific to handball matches. The active recovery is an effective alternative to maintain the positive effects of warming up on the body of handball players, significantly contributing to the optimal functioning of the cardiovascular and neuromuscular systems. Thus, we can state that ***the active recovery protocol, consisting of 15 minutes of warm-up at an effort intensity of 60% of FC_{max}, is a useful alternative to maintain the body's level of readiness for effort in optimal parameters and to improve handball players' motor and technical-tactical performance on the court.***

13.4. Elements of originality

So far, we have not identified any study that would conduct a comparative investigation of the effects of passive and active recovery on the body of handball players, when they are in substitute position, which lends our research originality and novelty.

The main element of originality brought by our intervention was the implementation of an **active recovery program** on the edge of the handball court, after the match warm-up, which consisted of **pedaling on stationary bikes** for 15 minutes at an effort intensity of 60% FC_{max}. This program aimed to maintain the benefits of the match warm-up on the major functions and systems of the body, directly involved in the effort specific to the handball game, thus allowing an increase in the motor and technical-tactical efficiency in the game.

Our scientific approach brings a series of elements of novelty and originality as early as the preliminary experimental research, in terms of the physical, physiological and on-court evaluation (motor and technical-tactical) of the handball players, using **unconventional methods and means of testing, measuring and monitoring**, that were chosen while taking into account both the individual characteristics of the athletes and the demands imposed by the modern game of handball.

The judicious choice and the correct implementation of the measurement and evaluation protocols led to obtaining precise data on the physical, physiological and efficiency capacity of all 12 players, in the different testing moments designed for our research. The use of these **technological innovations** is an element of novelty by the unique way in which information is collected, processed and transmitted to specialists, coaches or athletes. With their help, we were able to demonstrate that the recovery period (passive or active) is a factor influencing the performance on the court, of handball players.

The tests used in each evaluation protocol to identify changes in the neuromuscular and cardiorespiratory systems, after the implementation of the passive and active recovery, were chosen in accordance with current requirements for handball players from the first minute of official matches, as were identified in studying the specialized literature.

Another novelty concerns the **biochemical investigations** by collecting blood samples, in the different testing moments of our experimental research, to identify any changes that occurred both after the period of inactivity and after the implementation of the active recovery.

The elaboration of the formula for quantifying the overall efficiency in the game (C.E.T.J.) is a novelty element proposed by our research, because it aimed to lend objectivity to the process of the handball players' technical-tactical evaluation, which is often done superficially, only by recording the ratio between the total number of goals and the total number of shots. *This formula can become a very useful tool in the process of evaluating their own players, male or female, for coaches only under the conditions of standardizing all actions in the game, specific to their own tactical strategy, and under the conditions of prior knowledge of* *heart rate values (internal stresses) imposed by the execution of all these actions (external stresses).*

The players' level of efficiency included in the research, quantified by the implementation of this innovative formula, which includes all the actions performed during the rounds of the bilateral training match, is impossible to compare with other studies, because we could not identify an identical or similar method of evaluation, in women's handball.

13.5. Methodological proposals

1) We recommend using the passive recovery when the rest interval on the edge is shorter than 2-3 minutes (Buchheit & Laursen, 2013). If this duration is exceeded, but especially in the case of substitute athletes, who remain on the sidelines after the start of the match, we recommend using the active recovery so that the benefits of the warm-up are maintained and the athletes respond effectively to all subsequent strains on the court when they are introduced into the game.
2) Determining the effort intensity during the active recovery requires rigorous documentation and prior physical testing to determine the maximum exercise capacity by reference to the maximum heart rate (FC_{max}) or the maximum oxygen uptake (VO_{2max}). We propose that setting the intensity of the active recovery program should not exceed an effort of more than 60% of the maximum aerobic potential.
3) With regard to body temperature, although the active recovery resulted in the maintenance of a significantly better value of 37.37°C after 15 minutes of pedaling, when compared to the passive recovery (36.09°C), the decreases from the values obtained after the match warm-up, although minor, are statistically significant. For this reason, we recommend a combination of active warm up strategies on the edge of the court with passive warm up strategies, such as wearing thermal equipment, allowed by regulation (high neck tops/sweatshirts, calf sleeves, wristbands, etc.).
4) We recommend the development of strategies for exchanging the players, depending on the physical training, health and value level of the available group. The chances that the pace and quality of the collective game will be affected are less in the case of an efficient management of the rotation between the players.
5) Highlighting the strengths and weaknesses of each player evaluated based on the calculation formula introduced in our study, allows coaches to develop physical or technical-tactical training programs tailored to individual needs identified during competitions.

13.6. Research directions

1) We aim to identify the incidence of injuries due to a poor preparation of the body for effort and then to test the influence of the active recovery in reducing the risk of injury for substitute players, when they are introduced for the first time in the match.
2) Because the physical and physiological stresses during matches are specific to each playing position (Belka et al., 2016), we aim to identify the existence of statistically significant differences following the implementation of the active recovery protocol between players undergoing this research.
3) In order to simplify the evaluation process based on the coefficients proposed in our research, we will follow *the transposition of all calculation formulas into an automated software for monitoring and recording all actions during matches*, which can provide statistical data both during competitions and subsequently for further analysis of each player's evolution.
4) Although it was not on the list of our study's main objectives, it would be interesting to follow the evolution of physiological indices by statistically comparing the data recorded in the three testing moments: in the locker room (before warm up), immediately after warm up and at the end of the passive/active recovery.
5) Another direction of research will be the comparative analysis of the effects of passive recovery and active recovery on the mental capacity of substitute players, by applying specific tests to assess the level of concentration, motivation, anxiety, etc., before entering the match.

SELECTIVE BIBLIOGRAPHY

1. Ahmaidi, S., Granier, P., Taoutaou, Z., Mercier, J., Dubouchaud, H., & Prefaut, C. (1996). Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Medicine and Science in Sports and Exercise*, *28*(4), 450–456. https://doi.org/10.1097/00005768-199604000-00009.
2. Aloui, G., Hermassi, S., Hayes, L. D., Shephard, R. J., Chelly, M. S., & Schwesig, R. (2021). Effects of Elastic Band Plyometric Training on Physical Performance of Team Handball Players. *Applied Sciences*, *11*(3), 1309. https://doi.org/10.3390/app11031309.
3. Alptekin, A., Aritan, S., & Harbili, E. (2017). Investigation of Joint Reaction Forces and Moments During the Countermovement and Squat Jump. *Pamukkale Journal of Sport Sciences*, *8*(3), 58–71.
4. Anderson, P., Landers, G., & Wallman, K. (2014). Effect of warm-up on intermittent sprint performance. *Research in Sports Medicine (Print)*, *22*(1), 88–99. https://doi.org/10.1080/15438627.2013.852091.
5. Arazi, H., Mosavi, S., Basir, S., & Karam, M. (2012). The effects of different recovery conditions on blood lactate concentration and physiological variables after high intensity exercise in handball players. *Sport Science*, *5*, 13–17.
6. Arslan, E., Alemdaroglu, U., Koklu, Y., Hazir, T., Muniroglu, S., & Karakoc, B. (2017). Effects of Passive and Active Rest on Physiological Responses and Time Motion Characteristics in Different Small Sided Soccer Games. *Journal of Human Kinetics*, *60*(1), 123–132. https://doi.org/10.1515/hukin-2017-0095.
7. Bartlett, R. (1999). *Sports biomechanics: Reducing injury and improving performance*. E & FN Spon. ebook ISBN 9780203474563. https://doi.org/10.4324/9780203474563.
8. Baștiurea, E. (2002). *Handbal*. Editura Fundației Universitare, ISBN 973-8352-25-8.
9. Baștiurea, E. (2007). *Handbal-Concepte, principii și căi de perfecționare ale antrenamentului.* Editura Academica, Galați.
10. Baștiurea, E. (2014). *Handbal—Aspecte teoretice privind capacitatea motrică specifică posturilor de joc*. Editura Zigotto, ISBN 978-606-669-061-4.
11. Baștiurea, E., Sârbu, D., & Stan, Z. (2001). *Handbal pas cu pas*. Editura Evrika, ISBN 973-8052-79-3.
12. Baştiurea, E., Stan, Z., Rizescu, C., Mihăilă, I., & Andronic, F. (2014). The Effect of Muscle Strength on the Capacity of Coordination in Handball. *Procedia - Social and Behavioral Sciences*, *137*, 3–10. https://doi.org/10.1016/j.sbspro.2014.05.244.
13. Beattie, K., & Flanagan, E. (2015). Establishing the Reliability & Meaningful Change of the Drop-Jump Reactive-Strength Index. *Journal of Australian Strength and Conditioning*, *23*, 12.
14. Belka, J., Hulka, K., Safar, M., & Weisser, R. (2016). External and internal load of playing positions of elite female handball players (U19) during competitive matches. *Acta Gymnica*, *46*(1), 12–20. https://doi.org/10.5507/ag.2015.025.
15. Bělka, J., Hulka, K., Safar, M., Weisser, R., & Samcova, A. (2014). Analyses of Time-Motion and Heart Rate in Elite Female Players (U19) during Competitive Handball Matches. *Kinesiology*, *46*, 33–43.
16. Bilge, M. (2012). Game Analysis of Olympic, World and European Championships in Men's Handball. *Journal of Human Kinetics*, *35*(1), 109–118. https://doi.org/10.2478/v10078-012-0084-7.
17. Bishop, D. (2003a). Warm Up I: Potential Mechanisms and the Effects of Passive Warm Up on Exercise Performance. *Sports Medicine*, *33*(6), 439–454. https://doi.org/10.2165/00007256-200333060-00005.
18. Bishop, D. (2003b). Warm Up II: Performance Changes Following Active Warm Up and How to Structure the Warm Up. *Sports Medicine*, *33*(7), 483–498. https://doi.org/10.2165/00007256-200333070-00002.
19. Bogdanis, G. C., Nevill, M. E., Lakomy, H. K. A., Graham, C. M., & Louis, G. (1996). Effects of active recovery on power output during repeated maximal sprint cycling. *European Journal of Applied Physiology and Occupational Physiology*, *74*(5), 461–469. https://doi.org/10.1007/BF02337727.

20. Bompa, T. (2001). *PERIODIZAREA: TEORIA ȘI METODICA ANTRENAMENTULUI*. Ex Ponto, Constanța, ISBN 0-88011-851-2.
21. Bompa, T., & Buzzichelli, C. A. (2015). *Periodization Training for Sports-Third Edition* (Third). Human Kinetics, ISBN 978-1-4504-6943-2.
22. Bosco C, Luhtanen P, Komi PV. (1983) A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol Occup Physiol*;50(2):273-82.
23. Buchheit, M. (2008). The 30-15 Intermittent Fitness Test: Accuracy for Individualizing Interval Training of Young Intermittent Sport Players. *The Journal of Strength & Conditioning Research*, *22*(2), 365–374. https://doi.org/10.1519/JSC.0b013e3181635b2e.
24. Buchheit, M., Al Haddad, H., Millet, G. P., Lepretre, P. M., Newton, M., & Ahmaidi, S. (2009). Cardiorespiratory and Cardiac Autonomic Responses to 30-15 Intermittent Fitness Test in Team Sport Players: *Journal of Strength and Conditioning Research*, *23*(1), 93–100. https://doi.org/10.1519/JSC.0b013e31818b9721.
25. Buchheit, M., Cormie, P., Abbiss, C. R., Ahmaidi, S., Nosaka, K. K., & Laursen, P. B. (2009). Muscle deoxygenation during repeated sprint running: Effect of active vs. passive recovery. *International Journal of Sports Medicine*, *30*(6), 418–425. https://doi.org/10.1055/s-0028-1105933.
26. Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine (Auckland, N.Z.)*, *43*(5), 313–338. https://doi.org/10.1007/s40279-013-0029-x.
27. Buchheit, M., Lepretre, P. M., Behaegel, A. L., Millet, G. P., Cuvelier, G., & Ahmaidi, S. (2009). Cardiorespiratory responses during running and sport-specific exercises in handball players. *Journal of Science and Medicine in Sport*, *12*(3), 399–405. https://doi.org/10.1016/j.jsams.2007.11.007.
28. Buchheit, M., Simon, C., Charloux, A., Doutreleau, S., Piquard, F., & Brandenberger, G. (2005). Heart Rate Variability and Intensity of Habitual Physical Activity in Middle-Aged Persons: *Medicine & Science in Sports & Exercise*, *37*(9), 1530–1534. https://doi.org/10.1249/01.mss.0000177556.05081.77.
29. Buchheit, M., & Simpson, B. M. (2017). Player-Tracking Technology: Half-Full or Half-Empty Glass? *International Journal of Sports Physiology and Performance*, *12*(s2), S2-35-S2-41. https://doi.org/10.1123/ijspp.2016-0499.
30. Cardinale, M., Whiteley, R., Hosny, A. A., & Popovic, N. (2017). Activity Profiles and Positional Differences of Handball Players During the World Championships in Qatar 2015. *International Journal of Sports Physiology and Performance*, *12*(7), 908–915. https://doi.org/10.1123/ijspp.2016-0314.
31. Carlos-Vivas, J., Marín-Cascales, E., Freitas, T. T., Perez-Gomez, J., & Alcaraz, P. E. (2019). Force-Velocity-Power Profiling During Weighted-Vest Sprinting in Soccer. *International Journal of Sports Physiology and Performance*, *14*(6), 747–756. https://doi.org/10.1123/ijspp.2018-0490.
32. Carrier, B., Barrios, B., Jolley, B. D., & Navalta, J. W. (2020). Validity and Reliability of Physiological Data in Applied Settings Measured by Wearable Technology: A Rapid Systematic Review. *Technologies*, *8*(4), 70. https://doi.org/10.3390/technologies8040070.
33. Charlton, P., Kenneally-Dabrowski, C., Sheppard, J., & Spratford, W. (2016). A simple method for quantifying jump loads in volleyball athletes. *Journal of Science and Medicine in Sport*, *20*. https://doi.org/10.1016/j.jsams.2016.07.007.
34. Chavda, S., Bromley, T., Jarvis, P., Williams, S., Bishop, C., Turner, A., Lake, J., & Mundy, P. (2017). Force-Time Characteristics of the Countermovement Jump: Analyzing the Curve in Excel. *Strength and Conditioning Journal*, *40*, 1. https://doi.org/10.1519/SSC.0000000000000353.
35. Chelly, M. S., Hermassi, S., Aouadi, R., Khalifa, R., Van den Tillaar, R., Chamari, K., & Shephard, R. J. (2011). Match Analysis of Elite Adolescent Team Handball Players: *Journal of Strength and Conditioning Research*, *25*(9), 2410–2417. https://doi.org/10.1519/JSC.0b013e3182030e43.
36. Chen, C.-H., Chang, C.-K., Tseng, W.-C., Chiu, C.-H., Dai, X., & Ye, X. (2021). Acute Effects of Different Warm-up Protocols on Sports Performance in Elite Male Collegiate Hand-

ball Players. *The Journal of Strength & Conditioning Research*. https://doi.org/10.1519/JSC.0000000000003547.
37. Crowther, R., Leicht, A., Pohlmann, J., & Shakespear-Druery, J. (2017). Influence of Rest on Players' Performance and Physiological Responses during Basketball Play. *Sports*, *5*(2), 27. https://doi.org/10.3390/sports5020027.
38. Cucinotta, D., & Vanelli, M. (2020). WHO Declares COVID-19 a Pandemic, *Acta Bio-Medica: Atenei Parmensis*, *91*(1), 157–160. https://doi.org/10.23750/abm.v91i1.9397
39. Delamarche, P., Gratas, A., Beillot, J., Dassonville, J., Rochcongar, P., & Lessard, Y. (1987). Extent of lactic anaerobic metabolism in handballers. *International Journal of Sports Medicine*, *8*(1), 55–59. https://doi.org/10.1055/s-2008-1025641.
40. Demeter, A. (1976). *Fiziologia sporturilor*. Editura Stadion.
41. Dodd, S., Powers, S. K., Callender, T., & Brooks, E. (1984). Blood lactate disappearance at various intensities of recovery exercise. *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology*, *57*(5), 1462–1465. https://doi.org/10.1152/jappl.1984.57.5.1462.
42. Dragnea, A. (1996). *Antrenament sportiv.* Bucureşti. Editura Didactică şi Pedagogică
43. Dragnea, A., Mate-Teodorescu, S. (2002). *Teoria sportului.* Editura Fest, București.
44. Drăgan, I. (1979). *Selecția medico-biologică în sport*. Editura Sport-Turism.
45. Drăgan, I. (2002). *Medicină sportivă*. Editura Medicală, ISBN 973-39-0494-5.
46. Draper, N., Bird, E. L., Coleman, I., & Hodgson, C. (2006). Effects of Active Recovery on Lactate Concentration, Heart Rate and RPE in Climbing. *Journal of Sports Science and Medicine*, *05*(1), 97–105.
47. Dupont, G., Blondel, N., & Berthoin, S. (2003). Performance for short intermittent runs: Active recovery vs. passive recovery. *European Journal of Applied Physiology*, *89*(6), 548–554. https://doi.org/10.1007/s00421-003-0834-2.
48. Edholm, P., Krustrup, P., & Randers, M. B. (2014). Half-time re-warm up increases performance capacity in male elite soccer players. *Scandinavian Journal of Medicine & Science in Sports*. https://doi.org/10.1111/sms.12236.
49. Elder, J. W., Baraff, S. B., Gaschler, W. N., & Baraff, L. J. (2015). Pulse Oxygen Saturation Values in a Healthy School-Aged Population. *Pediatric Emergency Care*, *31*(9), 645–647. https://doi.org/10.1097/PEC.0000000000000331.
50. Ferragut, C., Vila, H., Abraldes, J. A., & Manchado, C. (2018). Influence of Physical Aspects and Throwing Velocity in Opposition Situations in Top-Elite and Elite Female Handball Players. *Journal of Human Kinetics*, *63*(1), 23–32. https://doi.org/10.2478/hukin-2018-0003.
51. Ferrari, W., Vaz, V., Sousa, T., Couceiro, M., & Dias, G. (2018). Comparative Analysis of the Performance of the Winning Teams of the Handball World Championship: Senior and Junior Levels. *International Journal of Sports Science*, *8*(2), 43–49.
52. Fleureau, A., Lacome, M., Buchheit, M., Couturier, A., & Rabita, G. (2020). Validity of an ultra-wideband local positioning system to assess specific movements in handball. *Biology of Sport*, *37*(4), 351–357. https://doi.org/10.5114/biolsport.2020.96850.
53. Foretić, N., Rogulj, N., & Papi, V. (2013). Empirical model for evaluating situational efficiency in top level handball. *International Journal of Performance Analysis in Sport*, *13*(2), 275–293. https://doi.org/10.1080/24748668.2013.11868648.
54. Fransson, D., Vigh-Larsen, J. F., Fatouros, I. G., Krustrup, P., & Mohr, M. (2018). Fatigue Responses in Various Muscle Groups in Well-Trained Competitive Male Players after a Simulated Soccer Game. *Journal of Human Kinetics*, *61*(1), 85–97. https://doi.org/10.1515/hukin-2017-0129.
55. Gabbett, T. J., Sheppard, J. M., Pritchard-Peschek, K. R., Leveritt, M. D., & Aldred, M. J. (2008). Influence of closed skill and open skill warm-ups on the performance of speed, change of direction speed, vertical jump, and reactive agility in team sport athletes. *Journal of Strength and Conditioning Research*, *22*(5), 1413–1415. https://doi.org/10.1519/JSC.0b013e3181739ecd.
56. Galazoulas, C. (2012). Gradual decline in performance and changes in biochemical parameters of basketball players while resting after warm-up. *Eur J Appl Physiol, 112 (9):3327-34.* doi: 10.1007/s00421-012-2320-1. Epub 2012 Jan 20. PMID: 22262012.

57. Gellish, R. L., Goslin, B. R., Olson, R. E., McDonald, A., Russi, G. D., & Moudgil, V. K. (2007). Longitudinal modeling of the relationship between age and maximal heart rate. *Medicine and Science in Sports and Exercise*, *39*(5), 822–829. https://doi.org/10.1097/mss.0b013e31803349c6.
58. Georgescu, M. (1971). Eforturile anaerobe și aerobe în practica antrenamentului sportiv modern. In *Conținutul și metodica antrenamentului sportiv* (p. 446). Editura Stadion.
59. Gheorghe, C., & Mereuță, C. (2019). *THE IMPACT OF A TOP PLAYER INJURY ON ROMANIAN NATIONAL HANDBALL TEAM PERFORMANCE AT THE FRANCE EHF EURO 2018*. 24–30.
60. Gheorghe, C., Mereuță, C. (2020). *Similarities and differences in the Attack of the Romanian Women's Handball Team at the IHF WWC 2019 and the EHF EURO 2018,* International Scientific Conference„Youth in the Perspective of the Olympic Movement", 27-28 february, 2020, Brașov, Romania (poster) Bulletin of the Transilvania University of Braşov.
61. Giblin, G., Tor, E., & Parrington, L. (2016). The impact of technology on elite sports performance. *Sensoria: A Journal of Mind, Brain & Culture*, *12*(2). https://doi.org/10.7790/sa.v12i2.436.
62. Gisolfi, C., Robinson, S., & Turrell, E. S. (1966). Effects of aerobic work performed during recovery from exhausting work. *Journal of Applied Physiology*, *21*(6), 1767–1772. https://doi.org/10.1152/jappl.1966.21.6.1767.
63. Gorostiaga, E. M., Granados, C., Ibáñez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine*, *26*(3), 225–232. https://doi.org/10.1055/s-2004-820974.
64. Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, *44*(2), 139–147. https://doi.org/10.1007/s40279-014-0253-z.
65. Hammami, A., Zois, J., Slimani, M., Russel, M., & Bouhlel, E. (2018). The efficacy and characteristics of warm-up and re-warm-up practices in soccer players: A systematic review. *The Journal of Sports Medicine and Physical Fitness*, *58*(1–2), 135–149. https://doi.org/10.23736/S0022-4707.16.06806-7.
66. Harper, D.; Hobbs, S.; Moore, J. The 10 to 5 repeated jump test. A new test for evaluating reactive strength. In Proceedings of the British Association of Sports and Exercises Sciences Student Conference, Chester, UK, 12–13 April 2011.
67. Havolli, J., Bahtiri, A., Kambič, T., Idrizović, K., Bjelica, D., & Pori, P. (2020). Anthropometric Characteristics, Maximal Isokinetic Strength and Selected Handball Power Indicators Are Specific to Playing Positions in Elite Kosovan Handball Players. *Applied Sciences*, *10*(19), 6774. https://doi.org/10.3390/app10196774.
68. Hermansen, L., & Stensvold, I. (1972). Production and removal of lactate during exercise in man. *Acta Physiologica Scandinavica*, *86*(2), 191–201. https://doi.org/10.1111/j.1748-1716.1972.tb05325.x.
69. Hermassi, S., Hayes, L. D., & Schwesig, R. (2021). Can Body Fat Percentage, Body Mass Index, and Specific Field Tests Explain Throwing Ball Velocity in Team Handball Players? *Applied Sciences*, *11*(8), 3492. https://doi.org/10.3390/app11083492.
70. Hermassi, S., Laudner, K., & Schwesig, R. (2019). Playing Level and Position Differences in Body Characteristics and Physical Fitness Performance Among Male Team Handball Players. *Frontiers in Bioengineering and Biotechnology*, *7*. https://doi.org/10.3389/fbioe.2019.00149.
71. Hills, S., Aben, H., Starr, D., Kilduff, L., Arent, S., Barwood, M., Radcliffe, J., Cooke, C., & Russell, M. (2020). Body temperature and physical performance responses are not maintained at the time of pitch-entry when typical substitute-specific match-day practices are adopted before simulated soccer match-play. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2020.11.013.
72. Hoppe, M. W., Baumgart, C., Polglaze, T., & Freiwald, J. (2018). Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. *PloS One*, *13*(2), e0192708. https://doi.org/10.1371/journal.pone.0192708.
73. Jemni, M., Sands, W. A., Friemel, F., & Delamarche, P. (2003). Effect of Active and Passive Recovery on Blood Lactate and Performance During Simulated Competition in High Level

Gymnasts. *Canadian Journal of Applied Physiology*, *28*(2), 240–256. https://doi.org/10.1139/h03-019.

74. Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports Medicine (Auckland, N.Z.)*, *44*(6), 797–814. https://doi.org/10.1007/s40279-014-0164-z.
75. Karpan, G., Škof, B., Bon, M., & Šibila, M. (2015a). *ANALYSIS OF FEMALE HANDBALL PLAYERS' EFFORT IN DIFFERENT PLAYING POSITIONS DURING OFFICIAL MATCHES*. 8.
76. Karpan, G., Škof, B., Bon, M., & Šibila, M. (2015b). Analysis of female handball players' effort in different playing positions during official matches. *Kinesiology*, *47.* (1.), 100–107.
77. Karvonen, M. J., Kentala, E., & Mustala, O. (1957). The effects of training on heart rate; a longitudinal study. *Annales Medicinae Experimentalis Et Biologiae Fenniae*, *35*(3), 307–315.
78. Kilduff, L. P., West, D. J., Williams, N., & Cook, C. J. (2013). The influence of passive heat maintenance on lower body power output and repeated sprint performance in professional rugby league players. *Journal of Science and Medicine in Sport*, *16*(5), 482–486. https://doi.org/10.1016/j.jsams.2012.11.889.
79. Kniubaite, A., Skarbalius, A., Clemente, F. M., & Conte, D. (2019). Quantification of external and internal match loads in elite female team handball. *Biology of Sport*, *36*(4), 311–316. https://doi.org/10.5114/biolsport.2019.88753.
80. Laffaye, G., Wagner, P. P., & Tombleson, T. I. L. (2014). Countermovement jump height: Gender and sport-specific differences in the force-time variables. *Journal of Strength and Conditioning Research*, *28*(4), 1096–1105. https://doi.org/10.1519/JSC.0b013e3182a1db03.
81. Lake, J., Augustus, S., Austin, K., Mundy, P., McMahon, J., Comfort, P., & Haff, G. (2018). The Validity of the Push Band 2.0 during Vertical Jump Performance. *Sports*, *6*. https://doi.org/10.3390/sports6040140.
82. Lau, S., Berg, K., Latin, R. W., & Noble, J. (2001). Comparison of active and passive recovery of blood lactate and subsequent performance of repeated work bouts in ice hockey players. *Journal of Strength and Conditioning Research*, *15*(3), 367–371.
83. Laver, L., Landreau, P., Seil, R., & Popovic, N. (Eds.). (2018). *Handball Sports Medicine*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-55892-8.
84. Lima, R. F., Palao, J. M., & Clemente, F. M. (2019). Jump Performance During Official Matches in Elite Volleyball Players: A Pilot Study. *Journal of Human Kinetics*, *67*, 259–269. https://doi.org/10.2478/hukin-2018-0080.
85. Londeree, B. R., & Moeschberger, M. L. (1982). Effect of Age and Other Factors on Maximal Heart Rate. *Research Quarterly for Exercise and Sport*, *53*(4), 297–304. https://doi.org/10.1080/02701367.1982.10605252.
86. Lorival J. Carminatti, Carlos A. P. Possamai, Marcelo de Moraes, Juliano F. da Silva, Ricardo D. de Lucas, Naiandra Dittrich, Luiz G. A. Guglielmo. (2013) Intermittent versus Continuous Incremental Field Tests: Are Maximal Variables Interchangeable?. *Journal of Sports Science and Medicine* **(12)**, 165 - 170.
87. Lovell, R., Midgley, A., Barrett, S., Carter, D., & Small, K. (2013). Effects of different half-time strategies on second half soccer-specific speed, power and dynamic strength. *Scandinavian Journal of Medicine & Science in Sports*, *23*(1), 105–113. https://doi.org/10.1111/j.1600-0838.2011.01353.x.
88. Luteberget, L. S., Holme, B. R., & Spencer, M. (2017). Reliability of Wearable Inertial Measurement Units to Measure Physical Activity in Team Handball. *International Journal of Sports Physiology and Performance*, *13*(4), 467–473. https://doi.org/10.1123/ijspp.2017-0036.
89. Luteberget, L. S., & Spencer, M. (2017). High-Intensity Events in International Women's Team Handball Matches. *International Journal of Sports Physiology and Performance*, *12*(1), 56–61. https://doi.org/10.1123/ijspp.2015-0641.
90. MacDonald, K., Bahr, R., Baltich, J., Whittaker, J., & Meeuwisse, W. (2016). Validation of an inertial measurement unit for the measurement of jump count and height. *Physical Therapy in Sport*, *25*. https://doi.org/10.1016/j.ptsp.2016.12.001.

91. Manchado, C., Martínez, J. T., Pueo, B., Tormo, J. M. C., Vila, H., Ferragut, C., Sánchez, F. S., Busquier, S., Amat, S., & Ríos, L. J. C. (2020). High-Performance Handball Player's Time-Motion Analysis by Playing Positions. *Int. J. Environ. Res. Public Health*, 15.
92. Manchado, C., Tortosa-Martínez, J., Vila, H., Ferragut, C., & Platen, P. (2013). Performance factors in women's team handball: Physical and physiological aspects--a review. *Journal of Strength and Conditioning Research*, *27*(6), 1708–1719. https://doi.org/10.1519/JSC.0b013e3182891535.
93. Maric, D., Gilic, B., & Foretic, N. (n.d.). Monitoring the Internal and External Loads of Young Team Handball Players during Competition. *Sport Mont*, *19*(1), 19–23.
94. Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *Journal of Strength and Conditioning Research*, *18*(3), 551–555. https://doi.org/10.1519/1533-4287(2004)18<551:RAFVOS>2.0.CO;2.
95. Markström, J. L., & Olsson, C.-J. (2013). Countermovement jump peak force relative to body weight and jump height as predictors for sprint running performances: (In)homogeneity of track and field athletes? *Journal of Strength and Conditioning Research*, *27*(4), 944–953. https://doi.org/10.1519/JSC.0b013e318260edad.
96. McCrary JM, Ackermann BJ, Halaki M. A systematic review of the effects of upper body warm-up on performance and injury. *Br J Sports Med. 2015 Jul;49(14):935-42.* doi: 10.1136/bjsports-2014-094228. Epub 2015 Feb 18. PMID: 25694615.
97. McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. *Sports Medicine (Auckland, N.Z.)*, *45*(11), 1523–1546. https://doi.org/10.1007/s40279-015-0376-x.
98. McMahon, J. J., Rej, S. J. E., & Comfort, P. (2017). Sex Differences in Countermovement Jump Phase Characteristics. *Sports*, *5*(1), 8. https://doi.org/10.3390/sports5010008.
99. McMaster, D., Tavares, F., O'Donnell, S., & Driller, M. (2020). Validity of Vertical Jump Measurement Systems Validity of Vertical Jump Measurement Systems. *Measurement in Physical Education and Exercise Science*. https://doi.org/10.1080/1091367X.2020.1835664.
100. Michalsik, L. B. (2018a). On-Court Physical Demands and Physiological Aspects in Elite Team Handball. In *Handball Sports Medicine*. Springer, Berlin, Heidelberg. ISBN 978-3-662-55892-8.
101. Michalsik, L. B. (2018b). On-Court Physical Demands and Physiological Aspects in Elite Team Handball. In L. Laver, P. Landreau, R. Seil, & N. Popovic (Eds.), *Handball Sports Medicine* (pp. 15–33). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-55892-8_36.
102. Michalsik, L. B., & Aagaard, P. (2015). Physical demands in elite team handball: Comparisons between male and female players. *The Journal of Sports Medicine and Physical Fitness*, *55*(9), 878–891.
103. Michalsik, L. B., Aagaard, P., & Madsen, K. (2013). Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. *International Journal of Sports Medicine*, *34*(7), 590–599. https://doi.org/10.1055/s-0032-1329989.
104. Michalsik, L. B., Aagaard, P., & Madsen, K. (2015). Technical Activity Profile and Influence of Body Anthropometry on Playing Performance in Female Elite Team Handball. *The Journal of Strength & Conditioning Research*, *29*(4), 1126–1138. https://doi.org/10.1519/JSC.0000000000000735.
105. Michalsik, L. B., Madsen, K., & Aagaard, P. (2013). Match Performance and Physiological Capacity of Female Elite Team Handball Players. *International Journal of Sports Medicine*, *35*(07), 595–607. https://doi.org/10.1055/s-0033-1358713.
106. Michalsik, L. B., Madsen, K., & Aagaard, P. (2015). Technical Match Characteristics and Influence of Body Anthropometry on Playing Performance in Male Elite Team Handball: *Journal of Strength and Conditioning Research*, *29*(2), 416–428. https://doi.org/10.1519/JSC.0000000000000595.
107. Mohr, M., Krustrup, P., Nybo, L., Nielsen, J. J., & Bangsbo, J. (2004). Muscle temperature and sprint performance during soccer matches—Beneficial effect of re-warm-up at half-time. *Scandinavian Journal of Medicine & Science in Sports*, *14*(3), 156–162. https://doi.org/10.1111/j.1600-0838.2004.00349.x.

108. Moss, S. L., McWhannell, N., Michalsik, L. B., & Twist, C. (2015). Anthropometric and physical performance characteristics of top-elite, elite and non-elite youth female team handball players. *Journal of Sports Sciences*, *33*(17), 1780–1789. https://doi.org/10.1080/02640414.2015.1012099.
109. Moss, S. L., & Twist, C. (2015). Influence of Different Work and Rest Distributions on Performance and Fatigue During Simulated Team Handball Match Play: *Journal of Strength and Conditioning Research*, *29*(10), 2697–2707. https://doi.org/10.1519/JSC.0000000000000959.
110. Myklebust, G., Skjølberg, A., & Bahr, R. (2013). ACL injury incidence in female handball 10 years after the Norwegian ACL prevention study: Important lessons learned. *British Journal of Sports Medicine*, *47*(8), 476–479. https://doi.org/10.1136/bjsports-2012-091862.
111. Myles, J. R., Lee, C. M., & Kern, M. (2017). The Influence of Various Recovery Modalities on Performance Tasks in Basketball Players. *International Journal of Applied Exercise Physiology*, *6*(1), 39–48. https://doi.org/10.22631/ijaep.v6i1.123.
112. Navalta, J. W., Montes, J., Bodell, N. G., Salatto, R. W., Manning, J. W., & DeBeliso, M. (2020). Concurrent heart rate validity of wearable technology devices during trail running. *PLoS ONE*, *15*(8). https://doi.org/10.1371/journal.pone.0238569.
113. Neumann, J., Morgenstern, O. (1944) *Theory of Games and Economic Behavior*, Princeton University Press.
114. Orange, S. T., Metcalfe, J. W., Liefeith, A., Marshall, P., Madden, L. A., Fewster, C. R., & Vince, R. V. (2019). Validity and Reliability of a Wearable Inertial Sensor to Measure Velocity and Power in the Back Squat and Bench Press. *Journal of Strength and Conditioning Research*, *33*(9), 2398–2408. https://doi.org/10.1519/JSC.0000000000002574.
115. Özsu, İ., Gurol, B., & Kurt, C. (2018). Comparison of the Effect of Passive and Active Recovery, and Self-Myofascial Release Exercises on Lactate Removal and Total Quality of Recovery. *Journal of Education and Training Studies*, *6*(9a), 33. https://doi.org/10.11114/jets.v6i9a.3511.
116. Pers, J., Bon, M., Kovacic, S., Sibila, M., & Dezman, B. (2002). Observation and analysis of large-scale human motion. *Human Movement Science*, *21*(2), 295–311. https://doi.org/10.1016/s0167-9457(02)00096-9.
117. Peterson Silveira, R., Stergiou, P., Carpes, F. P., Castro, F. A. de S., Katz, L., & Stefanyshyn, D. J. (2017). Validity of a portable force platform for assessing biomechanical parameters in three different tasks. *Sports Biomechanics*, *16*(2), 177–186. https://doi.org/10.1080/14763141.2016.1213875.
118. Petrigna, L., Karsten, B., Marcolin, G., Paoli, A., D'Antona, G., Palma, A., & Bianco, A. (2019). A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures. *Frontiers in Physiology*, *0*. https://doi.org/10.3389/fphys.2019.01384.
119. Pic, M. (2018). Performance and Home Advantage in Handball. *Journal of Human Kinetics*, *63*(1), 61–71. https://doi.org/10.2478/hukin-2018-0007.
120. Popa, M. (2004). *Statistică psihologică- cu aplicații SPSS-*. București: Editura Universității din București.
121. Póvoas, S. C. A., Ascensão, A. A. M. R., Magalhães, J., Seabra, A. F., Krustrup, P., Soares, J. M. C., & Rebelo, A. N. C. (2014a). Physiological Demands of Elite Team Handball With Special Reference to Playing Position: *Journal of Strength and Conditioning Research*, *28*(2), 430–442. https://doi.org/10.1519/JSC.0b013e3182a953b1.
122. Póvoas, S. C. A., Ascensão, A. A. M. R., Magalhães, J., Seabra, A. F. T., Krustrup, P., Soares, J. M. C., & Rebelo, A. N. C. (2014b). Analysis of Fatigue Development During Elite Male Handball Matches: *Journal of Strength and Conditioning Research*, *28*(9), 2640–2648. https://doi.org/10.1519/JSC.0000000000000424.
123. Póvoas, S. C. A., Seabra, A. F. T., Ascensão, A. A. M. R., Magalhães, J., Soares, J. M. C., & Rebelo, A. N. C. (2012). Physical and Physiological Demands of Elite Team Handball: *Journal of Strength and Conditioning Research*, *26*(12), 3365–3375. https://doi.org/10.1519/JSC.0b013e318248aeee.
124. Prudente, J. N., Cardoso, A. R., Rodrigues, A. J., & Sousa, D. F. (2019). Analysis of the Influence of the Numerical Relation in Handball During an Organized Attack, Specifically the

Tactical Behavior of the Center Back. *Frontiers in Psychology*, *0*. https://doi.org/10.3389/fpsyg.2019.02451.

125. Reche-Soto, P., Nieto, D., Diaz Suarez, A., Bastida-Castillo, A., Gómez-Carmona, C., García, J., & Pino Ortega, J. (2019). Player Load and Metabolic Power Dynamics as Load Quantifiers in Soccer. *Journal of Human Kinetics*, *69*, 259–269. https://doi.org/10.2478/hukin-2018-0072.
126. Reigal, R. E., Vázquez-Diz, J. A., Morillo-Baro, J. P., Hernández-Mendo, A., & Morales-Sánchez, V. (2020). Psychological Profile, Competitive Anxiety, Moods and Self-Efficacy in Beach Handball Players. *International Journal of Environmental Research and Public Health*, *17*(1), 241. https://doi.org/10.3390/ijerph17010241.
127. Rîșneac, B., Milici, D., & Rață, E. (2004). *Utilizarea tehnicii de calcul în evaluarea performanțelor sportive*. Editura Universității Transilvania.
128. Ronglan, L. T., Raastad, T., & Børgesen, A. (2006). Neuromuscular fatigue and recovery in elite female handball players. *Scandinavian Journal of Medicine & Science in Sports*, *16*(4), 267–273. https://doi.org/10.1111/j.1600-0838.2005.00474.x.
129. Russell, M., West, D. J., Harper, L. D., Cook, C. J., & Kilduff, L. P. (2015). Half-time strategies to enhance second-half performance in team-sports players: A review and recommendations. *Sports Medicine (Auckland, N.Z.)*, *45*(3), 353–364. https://doi.org/10.1007/s40279-014-0297-0.
130. Saavedra, J. M. (2018). Handball Research: State of the Art. *Journal of Human Kinetics*, *63* (1), 5–8. https://doi.org/10.2478/hukin-2018-0001.
131. Saavedra, J. M., Kristjánsdóttir, H., Einarsson, I. Þ., Guðmundsdóttir, M. L., Þorgeirsson, S., & Stefansson, A. (2018). Anthropometric Characteristics, Physical Fitness, and Throwing Velocity in Elite women's Handball Teams. *Journal of Strength and Conditioning Research*, *32*(8), 2294–2301. https://doi.org/10.1519/JSC.0000000000002412.
132. Sargeant, A. J. (1987). Effect of muscle temperature on leg extension force and short-term power output in humans. *European Journal of Applied Physiology and Occupational Physiology*, *56*(6), 693–698. https://doi.org/10.1007/BF00424812.
133. Sargent, D. A., (1921). The Physical Test of a Man, American Physical Education Review, 26:4, 188-194.
134. Scanlan, A. T., Wen, N., Tucker, P. S., & Dalbo, V. J. (2014). The Relationships Between Internal and External Training Load Models During Basketball Training: *Journal of Strength and Conditioning Research*, *28*(9), 2397–2405. https://doi.org/10.1519/JSC.0000000000000458.
135. Shargal, E., Kislev-Cohen, R., Zigel, L., Epstein, S., Pilz-Burstein, R., & Tenenbaum, G. (2015). Age-related maximal heart rate: Examination and refinement of prediction equations. *The Journal of Sports Medicine and Physical Fitness*, *55*(10), 1207–1218.
136. She, J., Nakamura, H., Makino, K., Ohyama, Y., & Hashimoto, H. (2014). Selection of suitable maximum-heart-rate formulas for use with Karvonen formula to calculate exercise intensity. *International Journal of Automation and Computing*, *12*, 62–69. https://doi.org/10.1007/s11633-014-0824-3.
137. Silva, L., Neiva, H., Marques, M., Izquierdo, M., & Marinho, D. (2018). Effects of Warm-Up, Post-Warm-Up, and Re-Warm-Up Strategies on Explosive Efforts in Team Sports: A Systematic Review. *Sports Medicine*, *1*. https://doi.org/10.1007/s40279-018-0958-5.
138. Skarbalius, A., Pukėnas, K., & Vidūnaitė, G. (2013). Sport Performance Profile in Men`s European Modern Handball: Discriminant Analysis between Winners and Losers. *Baltic Journal of Sport and Health Sciences*, *3*(90), Article 90. https://doi.org/10.33607/bjshs.v3i90.168.
139. Spierer, D. K. (2004). Effects of Active vs. Passive Recovery on Work Performed During Serial Supramaximal Exercise Tests. *International Journal of Sports Medicine*, *25*(2), 109–114. https://doi.org/10.1055/s-2004-819954.
140. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001 Jan;37(1):153-6. doi: 10.1016/s0735-1097(00)01054-8. PMID: 11153730.
141. Thorlund, J. B., Michalsik, L. B., Madsen, K., & Aagaard, P. (2008). Acute fatigue-induced changes in muscle mechanical properties and neuromuscular activity in elite handball players following a handball match. *Scandinavian Journal of Medicine & Science in Sports*, *18*(4), 462–472. https://doi.org/10.1111/j.1600-0838.2007.00710.x.

142. Tong, T. K., Baker, J. S., Zhang, H., Kong, Z., & Nie, J. (2019). Effects of Specific Core Re-Warm-Ups on Core Function, Leg Perfusion and Second-Half Team Sport-Specific Sprint Performance: A Randomized Crossover Study. *Journal of Sports Science & Medicine*, *18*(3), 479–489.
143. Toubekis, A. G., Peyrebrune, M. C., Lakomy, H. K. A., & Nevill, M. E. (2008). Effects of active and passive recovery on performance during repeated-sprint swimming. *Journal of Sports Sciences*, *26*(14), 1497–1505. https://doi.org/10.1080/02640410802287055.
144. Tudor, V. (2005). *Măsurare și evaluare în cultură fizică și sport*. Editura Alpha MDN. ISBN 973-787124-3.
145. Trofin, E. (1969). *Handbaliștii români și tactica jocului*. București: Editura Tiprarul.
146. Turki, O., Chaouachi, A., Behm, D. G., Chtara, H., Chtara, M., Bishop, D., Chamari, K., & Amri, M. (2012). The Effect of Warm-Ups Incorporating Different Volumes of Dynamic Stretching on 10- and 20-m Sprint Performance in Highly Trained Male Athletes: *Journal of Strength and Conditioning Research*, *26*(1), 63–72. https://doi.org/10.1519/JSC.0b013e31821ef846.
147. Vailshery, L. S. (2021). *Global connected wearable devices 2016-2022*. Statista. https://www.statista.com/statistics/487291/global-connected-wearable-devices/.
148. Valladares-Rodríguez, S., Rey, E., Mecías-Calvo, M., Barcala-Furelos, R., & Bores-Cerezal, A. J. (2017). Reliability and Usefulness of the 30-15 Intermittent Fitness Test in Male and Female Professional Futsal Players. *Journal of Human Kinetics*, *60*, 191–198. https://doi.org/10.1515/hukin-2017-0102.
149. Van Hooren, B., & Zolotarjova, J. (2017). The Difference Between Countermovement and Squat Jump Performances: A Review of Underlying Mechanisms With Practical Applications. *The Journal of Strength & Conditioning Research*, *31*(7), 2011–2020. https://doi.org/10.1519/JSC.0000000000001913.
150. Vărzaru, C. (2015). *Studiu cu privire la pregătirea jucătoarelor de handbal, specializate pe postul de extremă.* Universitatea Națională de Educație Fizică și Sport.
151. Wagner, H., Finkenzeller, T., Wuerth, S., & Von Duvillard, S. (2014). Individual and Team Performance in Team-Handball: A Review. *Journal of Sports Science & Medicine*, *13*, 808–816.
152. Wagner, H., Fuchs, P., & Michalsik, L. B. (2020). On-court game-based testing in world-class, top-elite, and elite adult female team handball players. *Translational Sports Medicine*, *3*(3), 263–270. https://doi.org/10.1002/tsm2.139.
153. Wagner, H., Orwat, M., Hinz, M., Pfusterschmied, J., Bacharach, D. W., von Duvillard, S. P., & Müller, E. (2016). Testing Game-Based Performance in Team-Handball. *The Journal of Strength & Conditioning Research*, *30*(10), 2794–2801. https://doi.org/10.1519/JSC.0000000000000580.
154. West, D. J., Russell, M., Bracken, R. M., Cook, C. J., Giroud, T., & Kilduff, L. P. (2016). Post-warmup strategies to maintain body temperature and physical performance in professional rugby union players. *Journal of Sports Sciences*, *34*(2), 110–115. https://doi.org/10.1080/02640414.2015.1040825.
155. Wik, E., Luteberget, L., & Spencer, M. (2017). Activity Profiles in International Women's Team Handball Using PlayerLoad. *International Journal of Sports Physiology and Performance*, *12*, 934–942. https://doi.org/10.1123/ijspp.2015-0732.
156. Wisloff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong Correlation of Maximal Squat Strength With Sprint Performance and Vertical Jump Height in Elite Soccer Players. *British Journal of Sports Medicine*, *38*, 285–288. https://doi.org/10.1136/bjsm.2002.002071.
157. Woods, A., Bishop, P., & Jones, E. (2007). Warm-Up and Stretching in the Prevention of Muscular Injury. *Sports Medicine (Auckland, N.Z.)*, *37*, 1089–1099. https://doi.org/10.2165/00007256-200737120-00006.
158. Yamada, E., Aida, H., Fujimoto, H., & Nakagawa, A. (2014). Comparison of Game Performance among European National Women's Handball Teams. *International Journal of Sport and Health Science*, *12*(0), 1–10. https://doi.org/10.5432/ijshs.201326
159. Yanaoka, T., Hamada, Y., Fujihira, K., Yamamoto, R., Iwata, R., Miyashita, M., & Hirose, N. (2020). High-intensity cycling re-warm up within a very short time-frame increases the sub-

sequent intermittent sprint performance. *European Journal of Sport Science*, *20*(10), 1307–1317. https://doi.org/10.1080/17461391.2020.1713901.

160. Yanaoka, T., Hamada, Y., Kashiwabara, K., Kurata, K., Yamamoto, R., Miyashita, M., & Hirose, N. (2018). Very-Short-Duration, Low-Intensity Half-Time Re-warm up Increases Subsequent Intermittent Sprint Performance. *Journal of Strength and Conditioning Research*, *32*(11), 3258–3266. https://doi.org/10.1519/JSC.0000000000002781.
161. Yanaoka, T., Iwata, R., Yoshimura, A., & Hirose, N. (2021). A 1-Minute Re-warm Up at High-Intensity Improves Sprint Performance During the Loughborough Intermittent Shuttle Test. *Frontiers in Physiology*, *11*. https://doi.org/10.3389/fphys.2020.616158.
162. Yanaoka, T., Kashiwabara, K., Masuda, Y., Yamagami, J., Kurata, K., Takagi, S., Miyashita, M., & Hirose, N. (2018). The Effect of Half-time Re-Warm up Duration on Intermittent Sprint Performance. *Journal of Sports Science & Medicine*, *17*(2), 269–278.
163. Zmijewski, P., Lipinska, P., Czajkowska, A., Mróz, A., Kapuściński, P., & Mazurek, K. (2020). Acute Effects of a Static vs. A Dynamic Stretching Warm-up on Repeated-Sprint Performance in Female Handball Players. *Journal of Human Kinetics*, *72*(1), 161–172. https://doi.org/10.2478/hukin-2019-0043.
164. Zois, J., Bishop, D., & Aughey, R. (2015). High-Intensity Warm-Ups: Effects During Subsequent Intermittent Exercise. *International Journal of Sports Physiology and Performance*, *10*(4), 498–503. https://doi.org/10.1123/ijspp.2014-0338.