PHYSICAL LOADING IN FLOORBALL MATCH – CROSS-SECTIONAL STUDY AT THREE DIFFERENT LEVELS OF SERIES

Jiri Kirsilä

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Supervisors: M.Sc. Mikko Häyrinen, PhD student
Marko Haverinen & PhD Juha Ahtiainen

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Joukkueurheilussa ottelukohtaisen kuormituksen selvittäminen on tärkeää lajin fysiologisten vaatimusten kannalta. Kilpailutilanteen tuottama vaste on tärkeä tietää, jotta harjoittelu on mahdollista suunnitella lähelle lajin fysiologisia vaatimuksia. Tämän tutkimuksen tarkoituksena oli selvittää korkeatasoisen salibandyottelun fysiologisia kuormitusvasteita, tarkastella eroja eri sarjatasojen välillä kokonaiskuormituksen ja eräkohtaisen kuormituksen kannalta, sekä selvittää ulkoisten ja sisäisten kuormitusmuuttujien yhteyksiä toisiinsa.

Tutkimus suoritettiin virallisissa salibandyliiton alaisissa sarjaotteluissa kauden 2021–2022 aikana. Tutkittavat sarjatasot olivat Pojat U18-SM-sarja, Pojat U21-SM-sarja SM ja Miehet F-Liiga. Tutkittavilta kerättiin otteluiden aikana sisäisen ja ulkoisen kuormituksen dataa Polar Team Pro -laitteiston avulla. Kerätyn datan osalta suoritettiin kaksiosainen rajaus, joiden perusteella lopullinen analysoitava aineisto koostui. Tutkittavien määrä oli 24 henkilöä, ja määrä jakautui tasaisesti kaikille kolmelle sarjatasolle (n = 8 / taso).

Ottelukuormituksen välisessä tasovertailussa kalorikulutus oli ainoa tilastollisesti merkitsevä ero ($p = 0.005$). Eräkohtaisessa vertailussa tasojen välillä ei eroja juurikaan ilmennyt, mutta tasokohtaisessa vertailussa huomattiin, että miesten eräkohtainen kuormitus korkean intensiteetin vaatimusten osalta oli kasvava, kun vastaavasti U18-tasolla kävi päinvastoin. Korkeimpien kiihdytys- (3.00 – 50.00 m/s^2) ja jarrutusnopeuksien (-50.00 – -3.00 m/s^2) määrä ottelussa ei tasojen välillä eronnut ($p = 0.204$ ja $p = 0.294$), mutta muuttujien välisessä vertailussa jarrutusten määrä oli tilastollisesti merkittävästi suurempi kaikilla tasoilla ($p = 0.005$). Sisäisen ja ulkoisen kuormituksen yhteyksiä löytyi huomattavasti enemmän miehiltä ja U21 tasoilta verrattuna U18 tasoon, ja miehillä yhteydet olivat selkeästi painottuneet korkean intensiteetin muuttujiin.

Salibandyottelu on kuormitukseltaan vaativampaa miesten kuin U18 tai U21 tasolla. Tämän tutkimuksen mukaan lajissa tapahtuu enemmän korkeimman nopeusalueen jarrutuksia kuin kiihdytyksiä sarjatasosta riippumatta. Erityisesti aikuisten tasolla korkean intensiteetin suorituskyvyllä on selkeitä yhteyksiä pelin tuottamiin fysiologisiin vasteisiin, mikä tulisi huomioida myös harjoittelussa eri ikävaiheissa. Tasojen välisiä eroja voidaan kuitenkin selittää iän, yksilön motorisen kehittymisen ja lajitaidollisten tekijöiden kautta.

Asiasanat: korkeaintensiteettinen, ottelukuormitus, eräkohtainen vertailu, joukkueurheilu

ABSTRACT

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In team sports, finding out the match-specific load is important in terms of the physiological requirements of the sport. It is important to know the response produced by the competition situation so that it is possible to plan training according to the physiological requirements of the sport. The purpose of this study was to find out the physiological load responses of a competitive floorball match, to examine the differences between three levels in terms of total match load and period-by-period, and to find out the associations between external and internal load variables.

This study was conducted in official floorball matches under the Finnish Floorball Federation during the 2021–2022 season. Investigated levels were U18 elite male junior, U21 elite male junior and Men's' elite level, F-league. Internal and external load data were collected from the subjects during the matches using Polar Team Pro -system. Regarding the collected data, a two-part inclusion criterion was performed, from which the results to be analyzed was composed. The number of subjects was 24, and the number was evenly distributed across all three levels (n = 8 / level).

When the match loads were compared between levels, calorie consumption was the only variable which differed statistically significantly ($p = 0.005$). In period-by-period comparison, there were not many differences between the levels, but within level comparison, it was noticed that the men's periodic load in terms of high intensity requirements was increasing, while the opposite happened at the U18 level. The number of the highest accelerations (3.00 – 50.00 m/s^2) and braking speeds (-50.00 – -3.00 m/s^2) in the match did not differ between the levels ($p = 0.204$ and $p = 0.294$), but in the comparison between the variables, the number of decelerations was significantly higher in all levels ($p = 0.005$). Associations between internal and external load were found significantly more in men and at the U21 level compared to the U18 level, and in men the associations were clearly focused on high intensity variables.

A floorball match is more demanding for men's level than for U18 or U21 level. According to this study, the number of decelerations is higher than the number of accelerations in the highest zones during a floorball match, regardless of the series level. At the adult level, high-intensity performance has clear associations to the physiological responses produced by the match, which should also be considered in training at different age. However, the differences between the levels can be explained by age, the development of the individual's motor skills and technical factors.

Key words: high-intensity, match load, period-by-period comparison, team sport

ABBREVIATIONS

ATP	Adenosine triphosphate
CK-MB	Creatine Kinase MB
COD	Change of direction
GPS	Global Positioning System
HR	Heart rate
HR_{max}	Maximal heart rate
hs-cTnT	High-sensitivity cardiac troponin T
IFF	International Floorball Federation
PFK	Phosphofructokinase
RSA	Repeated sprint ability
RSS	Repeated shuffle sprints
sRPE	Session ratings of perceived exertion
SSG	Small-sided games
TD	Total distance
TRIMP	Training-impulse
VO_2	Oxygen consumption
VO_{2max}	Maximal oxygen uptake

CONTENT

1 INTRODUCTION

Floorball has its roots as far back as 1958 in Minneapolis, USA, when the first versions of floorball, known as Cosom floor hockey, were reportedly played in the US and Canada. Since then, for today's floorball, the first modern sport was born in Sweden in the 1970s. The International Floorball Federation (IFF) was founded in 1986 by Sweden, Finland, and Switzerland. The popularity of the sport has risen rapidly, and today the IFF has 75 member countries, and the sport is played in more than 80 different countries. Countries with most registered players (table 1) are Sweden, Finland, Czech Republic, and Switzerland. (International Floorball Federation 2020.)

TABLE 1. Popularity of floorball in top countries (International Floorball Federation 2020).

Country	Registered players	Clubs	World Championships (Men)	World Championships (Women)	Medals (total)	Current ranking (Men)	Current ranking (Women)
Sweden	105 719	872	10	10	27	1	1
Finland	51 118	734	4	2	27	2	2
Czech Repuplic	41 404	411	0	0	6	3	4
Switzerland	33 325	396	0	1	18	4	3
Norway	9 037	289	0	0	3	6	7
Latvia	3 488	79	0	0	0	5	8

Floorball is played in an area of 40x20 m. The playing area is bordered by a movable rink with a height of 50 cm. Field markings must have a center line, as well as separately marked goalkeeper areas. The larger goalkeeper area is 4x5 m and has a 1x2.5 m area inside. A floorball match consists of three periods each lasting 20 minutes of effective playing time, with 10 – 15 minutes breaks between periods. If the result is tied after three periods of play, there will be 10 minutes of extra time played after two minutes of break, with a rule of a “golden goal” (team that scores next, wins the match). If the score after extra time is still tied, penalty shootout will be held to find the winner. Team can nominate a total of 20 players for the match protocol, which usually consist of 18 field players and two goalkeepers. The team can place five field players and one goalkeeper on the field. In a floorball match, there is therefore 5 vs 5 on the field at the same time, and in addition the goalkeepers of both teams. (International Floorball Federation 2020.)

Previously floorball has been defined as a submaximal speed endurance sport (Hokka 2001). Floorball could also be described as an intermittent team sport, which is defined as a sport that includes a high-intensity movement plays which include a sport-specific skills to be executed in a prolonged time from one to two hours (Baker et al. 2015). Although the sport itself has not changed much over time in terms of rules, the physical characteristics of the players may have evolved. What makes the definition of the sport and the characteristics problematic, is that there have been no previous scientific studies of the specific performance characteristics required in the sport, so the exact physiological definition of the sport remains unproven.

Elucidating the physical characteristics and loads accumulated from the matches contributes to the players' and coaches' understanding of the sport-specific requirements. By finding out the responses produced by match-specific load, we can analyze and plan training around the matches. Simultaneously, we can modify sport-specific training closer to the physiological requirements of the match, thus preventing the occurrence of unexpected situations in terms of physical performance. Investigating and understanding overall load from performance is important when planning training around the matches (McLaren et al. 2017). Determining the total load of the matches is important from the point of view of the total training load, and with the right kind of training, injuries can be prevented in floorball (Pasanen et al. 2008b).

The purpose of this study was to find out the total and period-by-period load of a single floorball match at three different levels, as well as to compare these loads between the levels. In addition, the aim was to find out the associations between internal and external load in a floorball match, and to compare possible associations between levels and draw conclusions about possible differences. This study was part of a larger research project (*Physical Game Analysis of Floorball*), the main authors of which were Marko Haverinen (Varala Sports Institute) and Elisa Hakamäki (Eerikkilä Sports Institute). The research was carried out in cooperation with the University of Jyväskylä, Varala Sports Institute, Eerikkilä Sports Institute, Finnish Institute of High-Performance Sport (KIHU) and the Finnish Floorball Federation.

2 CHARACTERISTICS OF FLOORBALL

2.1 Locomotion and neuromuscular demands in floorball

Floorball is an invasion sport which is played in indoor environment. In floorball, a player makes an average of 12-27 shifts in a single match, with a time-varying between 20 and 120 seconds, with a high number of changes of directions (Hokka 2001). There have been at least three other studies that has recorded men's floorball matches before, measuring players internal and external load during an actual regular season match. However, each studies have their weaknesses, since Hokka's (2001) external results were measured with pen and paper, Kainulainen's (2015) study included different internal measuring system when compared to other studies (Firstbeat Technology) and the external loading was measured with pen and paper. Kirsilä & Wenning (2019) seminar work is the closest since it has similar kind of study design and methods when compared to this thesis (Polar Team Pro -system). In the development of floorball as a sport, physical abilities are important qualities that develop player's ability to perform better in the match. Since not much research has been done on floorball, movement in the field needs to be viewed from the perspective of studies made on other sports.

Movement in the game has been studied in several different sports. Regarding the physiological demands and movement in the game, analysis has been done at least in soccer (also known as football), basketball, futsal, and handball (Taylor et al. 2017). However, each sport has a specific way of locomotion, which is determined by the rules of the sport and the method of moving the equipment that is used. In basketball, adult male players move an average of 6300 m per match, and correspondingly, junior male players move up to 7558 m per match. Results from total distance (TD) traveled in a match partly explain the fact that junior male players travel significantly more during sprints than adults. However, it should be noted that the junior male results are based on one study only. (Taylor et al. 2017.) Similarly in futsal, an elite player travels an average of 4313 m per match, of which approximately 8.9 ± 3.4% consists of sprints (Dogramaci et al. 2011). Each sport has its own characteristics (i.e., field size, number of players, playing time, game equipment and rules), so no sport can be directly compared to another. Distances traveled in different sports have been collected in table 2.

TABLE 2. Median values from different sports included (adapted from Taylor et al. 2017)

Movement category	Player type	Soccer	Basketball	Handball	Futsal
Total Distance (m)	Male	10794	6300	3855	4313
	Junior male	6175	7558*	1777*	NR
Lateral movement distance (m)	Male	316*	208	468	NR
	Junior male	381	125*	NR	NR
Jump frequency	Male	10*	48	19*	NR
	Junior male	4*	35	89*	NR

NR = Not reported, * = based on one study.

In basketball, it has been noticed that neuromuscular capacity can decrease during the season, depending on the match schedule and the frequency of the games. Neuromuscular demands of the matches seem to weaken when the importance of the matches increases, and the match schedule tightens up. (Petway et al. 2020.) In high-intensity sports, this issue has been studied through small-sided games (SSG), where the aim has been to either sustain or develop neuromuscular performance. Dello Iacono et al. (2016) conducted a study comparing the development of physical characteristics of elite male handball players between SSG and repeated shuffle sprints (RSS). The results of both exercise programs showed improvement after an eight-week observation period, although specific physical variables differed. The SSG group developed more on the agility and throwing skills, while the RSS group developed more on the 10 m and 20 m linear speeds and countermovement jump (CMJ), when compared to the SSG group. However, use of both training models was found to be useful when discovering different methods to train repeated sprint ability (RSA) at the last period of the season. (Dello Iacono et al. 2016.)

Before earlier mentioned study, Dello Iacono et al. studied the differences between SSG and high-intensity intermitted training (HIIT) in 2015 with elite men handball players, and the results were like the study conducted afterwards (Dello Iacono et al. 2015). A study by Attene et al. (2015) on the training of young basketball players also provided indications in this direction. In addition, Bosco et al. (1996) studied professional football players from internal load perspective, and the most significant finding were from blood testosterone levels. A high correlation between blood testosterone levels and explosive performance was found when investigating associations between field tests and hormonal responses. Correspondingly, a negative correlation ($r = -0.49$, $p = 0.004$) was found when investigating association between Cooper's endurance test and basal level of testosterone. (Bosco et al. 1996.) These results underline the importance of neuromuscular training across the whole season because the impact of short and high-intensity performances on the hormonal system and thus on the performance in the high-intensity sport can be more significant than thought during the season.

However, for understanding the movement development and neuromuscular demands, and their response produced, it is necessary to know the factors that regulate the training load. The load can be divided into three different adjustable areas, volume, intensity, and frequency. Volume is used to measure the amount of work done, while intensity is used to measure different performance changes during training or playing. Changes in intensity can be changes in speed, changes in time spent in different heart rate zones, or time spent at different lactate levels. Intensity regulation is mostly done by changes in performance speed and duration. Correspondingly, frequency often means the number of times per week, for example, or similarly how frequently the exercise or performances are done, thus referring to the amount of recovery from the previous exercise. (Casado et al. 2022; Wernbom et al. 2007.)

2.1.1 Volume

Training volume usually refers to the number of repetitions or sets per training session, but it can also be measured through sum of repetitions, sets or even training sessions. The volume can also be used as a descriptor of the total load of the exercise in terms of the work done. For example, in strength training the number of stretching- and shortening times of the muscle are added together. In strength training, it is more essential for development to calculate the training volume per muscle group than just the training volume per movement. This is due to the fact that in a single training program there may be several movements targeting the same muscle group, in which case the total volume of the muscle group being exercised can be better determined precisely through the volume of the muscle group. (Rhea et al. 2003; Wernbom et al. 2007.)

The total volume can also be described as the total workload, which is used to measure the athletes' total amount of work, especially in team sports. The most common measured variable in the total load is the distance traveled, to which the athletes' session rating of perceived exertion (sRPE) estimates have also been added. Depending on the study, the total load has been used to investigate either increased or decreased injury-risk (Bowen et al. 2017; Colby et al. 2014; Cummins et al. 2018; Murray et al. 2017) or to optimize training by regulating the amount of total load (Amirthalingam et al. 2016; Krieger 2010). However, it should be noted that no single variable is directly associated to an increased risk of injury, but the increase in injury-risk is often the sum of several variables (Kupperman & Hertel 2020).

2.1.2 Intensity

Measuring intensity usually requires a scale based on which performance is divided into low-, moderate-, and high-intensity performances. Intensity can be measured, for example, according to the predefined heart rate (HR) zones, in which case training intensity can be defined by weighting the different HR zones (Seiler 2010). Another example of intensity regulation in training is based on measurements of lactate levels. By finding out the lactate levels and monitoring the heart rate, it is possible to control the athlete's training by regulating the lactate levels. The simplest example of intensity training implemented through lactate values is when you aim to train as close as possible to the maximal lactate steady state (MLSS) state, where the body's energy production still mainly takes place via oxidative pathways instead of anaerobic pathways. Anaerobic energy metabolism activates when body’s lactate concentration exceeds MLSS limit, when the body is no longer able to eliminate the accumulated lactate in the same proportion as needed. (Beneke & von Duvillard 1996; Seiler & Kjerland 2006.)

Intensity regulation has already been used to find out the possible risk of injury in long-lasting high-intensity training periods. It has been found that two weeks of high-intensity training increases injury-risk for the following week, but contradictory, four weeks of high-intensity training shows a reduction in injury-risk, at least on the rugby side. (Cummins et al. 2018.) In case of physiological development, intensity duration has also been used to determine the effects of exercise on maximal oxygen uptake (VO_{2max}) values. Kelly et al. (2018) investigated the effect of sprint interval training (SIT) and endurance training (ET) on performance on the development of endurance. Subjects were Gaelic football players (n = 15, mean age 21.7 ± 2.8 years). Study lasted 2 weeks, in which both groups performed three training sessions per week. ET group practise session included 50 minutes of steady state running at 75 % of HRmax per session. SIT group performed three sets of three sprint intervals, with the distance of 110 m in one sprint, including several changes of directions and forward and backwards running. Recovery between each sprint was 20 s, and 5 minutes between sets. Both resulted improvements in time effect for VO_{2max} values ($p = 0.008$), but also in high intensity exercise capacity ($p = <0.001$). (Kelly et al. 2018.)

2.2 Energy metabolism and cardiorespiratory demands in floorball

Playing floorball has beneficial effects on health, which can be seen regardless of age. Pedersen et al. (2018) performed a 26-month follow-up period, where adults aged between 66 and 78 years practiced floorball 1.7 times a week for 40 min/week (n = 15). Compared to the control group (n = 16), the statistical significances showed that floorball slowed down the decrease in elderly VO_{2max} values, leg bone density improved, and blood glycosylated hemoglobin decreased less. Similarly, Larsen et al. (2020) studied the daily (5x/week) effect of short 12-minute high-intensity exercise on the health of 8-10-year-old children. The forms of movement were interval running (n = 57) or small-sided games (n = 60) where the sports were football, basketball, and floorball, 3vs3 or 4vs4 as a game format. In addition, a control group (n = 115), which carried out a normal everyday life. Both interval running and small games elicited cardiac adaptations compared to control group. Small-sided games group had statistically significant increase in interventricular septum thickness compared to control group (0.30 ± 0.87 vs. –0.15 ± 0.68 mm, $p < 0.05$). Interval group had larger decrease in left ventricular systolic diameter (–1.49 ± 2.94 vs. 2.94 ± 0.98 mm, $p < 0.05$). (Larsen et al. 2020.)

In floorball, energy metabolism is focused on interval-type work, in which case energy production methods can be divided into two categories, aerobic and anaerobic energy production. Depending on the length and intensity of the load, the relative share of the energy production method varies. (Hokka 2001.) An exact energy metabolism ratio has not been measured for floorball, so the estimates are based more on comparisons of other similar sports and energy metabolism studies. For example, in ice hockey, energy metabolism is distributed according to the model 69% of anaerobic vs 31% of aerobic energy metabolism (Leger et al. 1979).

2.2.1 Aerobic energy production and performance

Floorball has previously been described as a submaximal speed endurance sport, which includes a high number of changes of direction along the game (Hokka 2001). The human body is capable to produce ATP on aerobic level, and it is shown that even 50 % increase of aerobic training in two weeks increases subsarcolemmal and intermyofibrillar muscle mitochondria capacity to generate ATP in aerobic level. (Spina et al. 1996; Starritt et al. 1999.) Therefore, higher level of basic aerobic endurance is warranted also in floorball. Not many studies have addressed aerobic performance in floorball, although it is mentioned to be important part on developing other sport specific qualities (Kainulainen 2015). Several other sports have reported its benefits and necessity in their own sports as well.

Athletes with good oxygen consumption (VO_2) levels would seem to travel longer distances in football matches, emphasizing the importance of aerobic performance (Bangsbo & Lindquist 1992). Similarly, basic aerobic fitness condition for energy production helps maintain better anaerobic performance, as aerobic energy production is better able to meet the body's energy needs in high-intensity performance (Balsom et al. 1994). In addition, research has been carried out on the football to verify that a player with better aerobic performance can perform more varied in terms of the requirements of the game, such as distance traveled, oxygen consumption or number of sprints. In addition to these, benefits have also been found in terms of recovery after high-intensity intervals. (Balsom et al. 1994; Tomlin & Wenger 2001.) Although it should be mentioned, that when comparing football and floorball, we are speaking with two different sports. When evaluating the physiological requirements of different sports, the VO_{2max} gives a perspective of respiratory system needed. Different kind of VO_{2max} values are presented in table 3.

TABLE 3. $VO2_{max}$ values in different sports.

Sport	n	$VO2_{max}$ (ml/min/kg)	Study
Soccer	930	51.0 ± 2.0 - 69.8 ± 6.6	Stølen et al. 2005
Futsal	458	48.6 ± 3.9 - 65.1 ± 6.2	Spyrou et al. 2020
Basketball	–	50.0 - 60.0	Ziv & Lidor 2009
Handball	41	57.0 ± 4.1	Michalsik et al. 2015
Ice-hockey	162	55.9 ± 5.2	Ferland et al. 2021

Narazaki et al. (2009) studied the effects of a simulated half basketball game and measured, among other variables, the average VO_2 during a basketball game, and conclusions could be drawn especially regarding the significance of aerobic performance. Based on the study, it appears that both men and women have a clear benefit from good aerobic performance in a competitive match. Similar results have been reported from the futsal side when Milanez et al. (2011) studied futsal players effect of $VO2_{max}$ on perceived training load. Twist & Rhodes (1993) argued that in ice-hockey, players with better aerobic performance can play longer in the high-intensity level. Greater aerobic performance delays fatigue, which in turn affects the player's ability to produce the game at a high-intensity level. Although hockey is especially known as a high-intensity game, the recovery between the shifts takes place mainly on an aerobic level. The same phenomenon can also be seen from heart rate measurements on the floorball (Hokka 2001; Kainulainen 2015; Kirsilä & Wenning 2019).

2.2.2 Anaerobic energy production and performance

Because floorball can be described as a high-intensity intermittent team sport that involves a high number of changes in direction, energy formation occurs primarily through anaerobic glycolysis. The argument is supported by the average shift length in floorball, which is between 20 and 120 s (Hokka 2001). However, the first immediate energy sources are formed through the ATP-PCr system, which can guarantee a sufficient energy supply for 5–8 s, after which the energy formation changes shape (see figure 1), closer to the short-term glycolytic energy system characteristic. Anaerobic glycolysis is activated especially when the run takes about 60 to 180 seconds. However, anaerobic system capacity is limited, although it can respond to energy demands in a short period of time. It does not mean that the method of energy production is not running, but the ratio to the amount produced is then at its highest. In addition, importance of aerobic energy production cannot be sidelined. (Gastin 2001.)

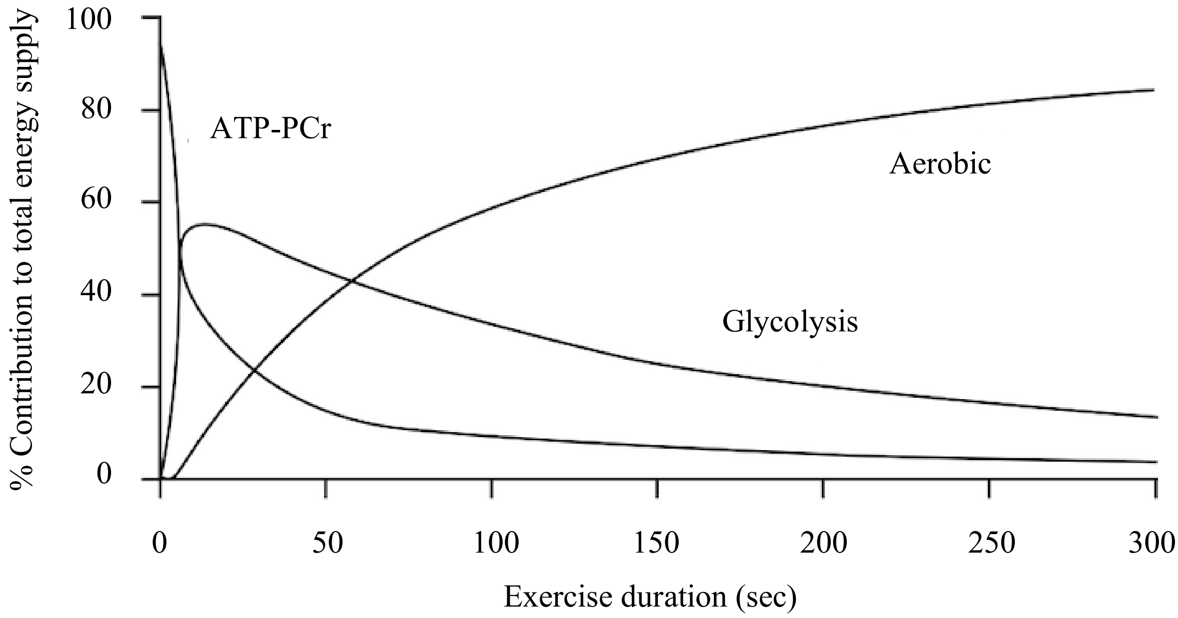

FIGURE 1. Different energy production pathways and emphasis during maximal performance (adapted from Gastin 2001).

In prolonged exercise, lactate and lactate buffering mechanisms also become an additional factor in energy production. The lactate levels in floorball match range from the lowest measured values of 4.28 ± 2.12 mmol / l to the highest of 5.45 ± 2.07 mmol / l (Hokka 2001). As physical activity progresses to the anaerobic level, the accumulation of lactate in the blood exceeds the body's ability to remove / benefit from lactate, leading to relative tissue hypoxia. That is, systems that convert ATP, which is important for the body's energy needs, lose their potency due to high lactate accumulation. It is known that speed endurance training leads to a greater lactate accumulation than speed training both in blood and muscle (Mohr et al. 2007). Therefore, as the time of exercise arises, athletes' fatigue is often described because of high lactic acid concentrations in the muscles, or correspondingly due to acidification. In reality, it is about the accumulation of lactic acid and lactate in the blood, but which in themselves are not yet explanatory factors for fatigue. Lactate actually has positive effects on intramuscular ATP production, and it is also assumed to be a metabolic fuel for cells other than working muscle. (Cairns 2006; Gladden 2004.) On the contrary, glycolytically generated energy produces lactic acid, which releases hydrogen ions into the bloodstream. The hydrogen ion concentration in the bloodstream also produces acidity, which causes, for example, a weakening of isometric force output during muscle contraction, and can therefore also be one of the explanatory factors of fatigue during exercise. (Ament & Verkerke 2009.)

Muscle cell types and their number in the muscles then play a significant role in energy production when more energy needs to be produced quickly. Particularly for anaerobic glycolysis, fast-twitch type II muscle cells can regenerate ATP significantly faster than type I slow-twitch muscle cells, which produce energy primarily aerobically. This is because fast-twitch type II muscle cells contain higher amounts of phosphofructokinase (PFK), making anaerobic glycolysis as a process more optimal compared to other forms of energy production. (Cairns 2006.) In particular, type II muscle cells are activated especially in higher strength demands (Suchomel et al. 2018), in which for example change of direction is.

3 EXTERNAL AND INTERNAL LOAD

Physical performance refers to the body's ability to perform a certain type of activity, which can be defined as either an external load or an internal load. Changes in physical performance can be verified by the test results shown by the body's current performance. In this case, however, it must be understood that the model of the tests produced is likely to be implemented in terms of external loading. In other words, external loading is also known as 'physical work' such as running distance, number of high-intensity sprints or weights lifted. The test results obtained guide the perception of current performance. However, it would also be important to look at internal load indicators, such as heart rate values. (Gabbett 2016; Impellizzeri et al. 2005.) Although external load is a determining factor in performance measurements, it is not in itself the only factor affecting performance (Bouchard & Rankinen 2001).

Regardless of the sport, the studies have tried to find out the physiological load responses of different sports performances. In particular, the measurements of external and internal load have sought to produce knowledge about the physiological responses of different sports, with the help of which the athletes' training can be targeted through sport-specific characteristics. Depending on the sport, it is possible to find research data for both simulated matches and competitive matches, as well as from training sessions, where an effort has been made to monitor the athletes' perceived load from the sport-specific performance. The variables to be measured are heart rate variability, distance traveled, distance traveled in different speed ranges, accelerations, decelerations, and the athlete's perceived load from the performance. (Teixeira et al. 2021; Petway et al. 2020; Spyrou et al. 2020; Lignell et al. 2018; Stojanović et al. 2017.)

3.1 External loading

External loading refers to physical activity that tends to destabilize the homeostasis of the body. In most cases, the aim is to adjust the external load according to the volume, intensity, or frequency of the exercise. (Coffey & Hawley 2007.) When talking about the external load of the game and the functions related to the game, the various variables with which the external load can be verified should be considered. For example, in field sports such as floorball, external load variables may include the total distance traveled by individuals during a match, the number of changes in direction, the time spent in different speed zones, the distance traveled at different speeds zones, accelerations, and decelerations. The same applies to different internal load variables, because due to the external load, the internal load gets a stimulus (McLaren et al. 2017).

In terms of training monitoring, external load can be an easier factor to measure. For example, in high-intensity interval training, measuring devices for internal load may not be available. Similarly, for monitoring the external load, either the time spent, or the distance traveled during the exercise can be calculated. (Impellizzeri et al. 2019.) However, it is generally known that both load variables are connected to each other, so both external and internal load variables and results should be used in training monitoring (McLaren et al. 2017).

3.2 Internal loading

Internal loading is a reaction caused by the body's external loading or physical performance, in which the body's normal state of homeostasis is disrupted. To develop performance, the body needs a training stimulus that strains the body’s performance. In other words, exercise aims to produce a certain physiological stress response so that the body can better deal with this state of stress in the future. It is possible to target the stress response produced by training to, for example, maximal oxygen uptake (VO_{2max}) or adaptation of musculoskeletal mitochondria, depending on the training method and goals. (MacInnis & Gibala 2016.)

The internal load can be measured by means of heart rate variability, or by measuring the time spent in different heart rate zones over time. In floorball, heart rate measurement was used to measure internal load, allowing sport-specific physical performance needs to be identified (Kainulainen 2015; Kirsilä & Wenning 2019). However, measurements of internal loading can also be done from arterial blood sampling to better understand the load on the muscle cells in the body caused by the loading. These methods are known as cardiac biomarkers. (Carranza-García et al. 2011.) In addition, it is possible to use several other biomarkers as well, such as creatine kinase from muscles or lactate levels from bloodstream.

In floorball, not that much of a study have made that investigates the overall loading from floorball. There are a few studies that have investigated floorball from muscle cell point of view. Wedin & Henriksson (2014) conducted a study looking at the amount of muscle cell damage caused by floorball match. The study measured subjects' Creatine kinase MB (CK-MB), high-sensitivity cardiac troponin T (hs-cTnT), and myoglobin after a single floorball match. Measurements were taken before, immediately after and two hours after the match. A total of 23 elite male floorball players participated in the study, and the study included two different matches, having a 3-month time between measurements. The most significant finding that emerged from the study results was the clear increase in hs-cTnT values after the match load, and the same was repeated in the measurements of the second match. Notable mention as authors also underlined was, that six of the subjects' recorded hs-cTnT levels to reach over myocardial damage cutoff (≥ 14ng / l) in both games. (Wedin & Henriksson 2014.) More specifically, hs-cTnT is part of the troponin complex that controls calcium interaction between myosin and actin and is released into the circulatory system once cardiomyocytes have died. That is, when myocardial cell is damaged. (Sharma 2004.)

3.3 Measurement systems for internal and external load identification

The development of an athlete's performance is affected by the various stimulations produced through training, which can be regulated through volume, intensity, and frequency. Periodization of training aims to influence the amount and type of stimulation produced. To optimize the stimulation doses produced from training, it is necessary to pay attention to the monitoring of the performed training. For monitoring and analyzing, there are several different technological options available today, which can be used to obtain more detailed information about the training performed and the physiological responses it produces. When training is based on movement, the data produced by the athlete's movement in terms of both internal and external load is essential, if training is to be programmed in the most optimal way possible. (Impellizzeri et al. 2019; McLaren et al. 2017.)

3.3.1 GPS-based tracking system

As the information gathering and analysis arises along the way, different kind of technological solutions for data gathering are coming on everyday-based working nowadays. Global Positioning System (GPS) is one of the most used technological method for monitoring athletes overall load in different kind of actions, either in practices or actual games. As the GPS based tracking system is relatively inexpensive, several different sports and teams are using GPS based tracking system to monitor or evaluate their athletes internal and external loading. (Aughey 2011; Cunniffe et al. 2009; Varley et al. 2017.) The supply of a GPS-based tracking system is extensive today, and several manufacturers offer this method to monitor the movement of athletes on the field. There are also other methods for monitoring the athletes loading, such as Local Positioning System (LPS) or artificial video-based systems.

Several sports have already used GPS as a monitoring tool for measuring athletes’ movement. Especially football (also known as soccer) has numerous amounts of studies which have used GPS-based tracking system as a method of measuring external load on athletes. However, it is also mentioned, that different system providers may differ from one another, which means that so called ‘golden standard’ doesn’t yet exist (Cummins et al. 2013).

Early days GPS based tracking was used and developed for military use only but has since then spread to wider use (Malone et al. 2017). In team sports, the GPS-based tracking system has become increasingly used and is now widely in the daily lives of many teams (Aughey 2011; Buchheit & Simpson 2017). GPS system is an operational satellite system, which has numerous satellites in earth’s orbit. Each satellite has an atomic clock, which synchronizes the receiver to calculate the time in different measurements where the receiver is used. The speed of the signal between the receiver and the satellite is the same as speed of light. Comparing the time between the satellite and the receiver, it is possible to calculate the distance between satellite and receiver when multiplying signal travel time and speed of light. In terms of position tracking, at least four different satellites must be connected to the receiver at the same time. That is when it is possible to trigonometrically determine receivers’ position on earth. (Huggins et al. 2020; Larsson 2003.)

Alongside with GPS system, with the development of technology, various measurement methods have been added as part of the GPS equipment to improve the overall validity of the measurement system. Gyroscopes, magnetometers and triaxial accelerometers, also known as micro electrical mechanical systems (MEMS), are providing much more accurate and larger amount of data from athletes overall loading. (Malone et al. 2017.) These MEMS sensors may include all three different instruments, or just some of them.

3.3.2 GPS signal and accuracy

The GPS-based system uses signals at different frequencies. The first generated and known signal was an L1 signal at 1575.42 MHz. Correspondingly, the more advanced signal is the L2 signal, which was also more accurate and operated at 1227.6 MHz. (Kumar & Moore 2002.) However, the distance between the equipment becomes a problem, as a long signal travel distance can be easily disturbed along the way, causing an error estimate of centimeters or even tens of meters. Afterwards, GPS technology has also evolved, GPS devices will be able to receive multiple frequency signals simultaneously (Zhang et al. 2020).

Frequency is an essential factor to minimize connection reliability and margin of error. Frequency is measured in Hertz (Hz), which can be used to determine the data collected per second. Most GPS-based data acquisition methods favor a 10 Hz connection, although higher Hz amounts are also used. The strength of the connection determines the reliability of the results obtained in a simplified manner, as a lower frequency produces a higher margin of error in the measurement results. Partly for this reason and partly also because of the distance between the two devices, to ensure a reliable GPS connection, four satellites must be connected to the sensor at the same time. When at least four satellites are connected to the sensor, the continuous data transmission of the connection and the strength of the connection determine the reliability of the received data. (Rico-González et al. 2020)

The validity and reliability of the equipment used should be known to monitor truthful and optimal training so that the measured results are as close as possible to the actual values. Akyildiz et al. (2020) investigated the validity of the Polar Team Pro system in outdoor measurements. The study was conducted on eight volunteer amateur footballers with two Polar Team Pro GPS 10 Hz units in their chest. The subjects performed a simulated track with a length of 1200 m, including movements at different speeds. The results showed that the Polar Team Pro 10 Hz receivers were able to transmit data reliably at all variables. For example, the mean distance traveled of the subjects was 1201.92 ± 8.20 m. (Akyildiz et al. 2020)

Although GPS is widely used method for measuring movement, it is not that much studied on indoor environment as outdoor. There has been couple of either reviews or systematic reviews on outdoor studies that has used GPS-based system as a measuring method (Cummins et al. 2013; Theodoropoulos et al. 2020), yet from indoor environment, number of reviews or systematic reviews are most likely none. The GPS signal can be disturbed for example clouds, or tall buildings (Huggins et al. 2020). If measurements are taken inside the building, it is possible that the signal will be disturbed even more. Therefore, using a GPS system indoors can present challenges to validity (Fox et al. 2019). The connection required to generate a GPS signal to multiple satellites simultaneously is not a problem, but interfering factors on signal can cause more errors in the results compared to outdoor measurements.

Fox et al. (2019) studied the validity of the Polar Team pro system for indoor measurements. Twenty-six subjects participated in the study, and each was fitted with both a back-mounted sensor and a chest-mounted sensor. Subjects performed a continuous locomotive task (168.45 m) and COD test (40.0 m) three times in a random order, whether by walking, jogging, or with maximum speed. As a reference system, authors used trundle wheel and video system to track down subjects' movement. As a result, no significant differences were found between the sensor placements. However, in both cases sensors compared poorly with the reference system. Sensor either underestimated or overestimated both speed and distance covered. Speed was underestimated 2.76 km / h^{-1} and overestimated 4.52 km / h^{-1}. Total distance had underestimation of 32.6 m and overestimation of 59.6 m, creating a typical error of 11–50 % in speed and distance. However, there is a small change that the results may have discrepancy, since each trail were manually controlled. (Fox et al. 2019.) However, results show that measurements done in indoor environment via GPS-based tracking system should be looked carefully, because in reality, MEMS technology produces information regarding the movement performed indoors. Another method used is the LPS-based tracking system, also known as the Local Positioning System.

3.3.3 LPS-based tracking systems

Like most of the technological systems, LPS has also different kind of technological solutions behind it. The most important function of LPS system is to locate the target as accurately as possible, and this could be done with different types of ways, depending on which algorithm is used. Connection between the anchor and the sensor is one of the main differences in system providers since there are different kind of possibilities to use in connection signal. It is already proved to be more valid and reliable than GPS in indoor measurements (Bastida-Castillo et al. 2019), but still the number of studies behind LPS is rather small. Comparison between these two different measurement methods have been done earlier by Bastida-Castillo et al. (2018), when they compared GPS and UWB-based position-tracking system in football, investigating athlete's movement and the validity to measure it with GPS and LPS systems. In this study, even made on outdoors, the LPS system provided better accuracy on locomotion analysis. LPS system has an error of bias < 3.5 %, which can provide accurate and reliable data for objects locomotion. (Conte 2020.) However, it should be noted that depending on the study, the results vary, but the conclusions in terms of validity are consistent.

The system always requires separately installed measuring anchors to operate. Anchors are used to create a "bubble" that allows the measurements to be targeted to a specific area where the measurements are to be made. For outdoor measurements, separate stations must be built where the anchors can be installed. Correspondingly, indoor anchors can be implemented either in the same way, or anchors can be installed in structures located in the building, provided that the structures clearly cover the area that will be measured. However, the receivers are recommended to cover as much from the area that will be measured as possible, so that the accuracy is as good as possible (Vasilyev et al. 2017). It should be noted that two clear differences arise as a problem with the LPS system compared to other measurement systems. The LPS system is in a high price category, so the majority of users do not directly have the financial opportunity to use or order the equipment. Another problem is mobility, because after installation, the equipment can no longer be moved without a new installation and calibration. (Alarifi et al. 2016; Serpiello et al. 2017.)

3.3.4 LPS signal and accuracy

Two of the most used LPS signals are Radio-Frequency Identification- (RFID) and Ultra-wideband (UWB) signal. RFID signal is a wireless connection between two different devices. RFID is used to transmit information between predefined frequencies between the tags and the receivers. It is possible to be either passive or active tag that communicates with the receiver, although active tag requires more power, so the battery source is needed. Both active and passive tags have their own chip storage, which can have up to two (2) kilobytes of different data to be transmitted. (Alarifi et al. 2016.) RFID systems can use either a wave signal or a pulse. The signal is controlled by Hertz (Hz), which means that certain amount of Hz provides a certain amount of information, depending on the frequency the system is able to operate. The chips constantly transmit the information encoded in them, and the RFID system allows these to be detected and read. Thus, for example, in positioning systems, a chip given to athletes transmits information about its location at a certain frequency, and receivers read this information according to the frequency at which the chip transmits information. The biggest difference between LPS systems is in the form of a signal, i.e., whether it is a wave or pulse type frequency. (Irnich 2002.)

UWB signal differs from normal RFID signal in its form. Unlike other RFID signals, UWB signal is pulse-type of signal, instead of wave. In pulse form, the algorithms and measurements rely on time between pulses. Because UWB can produce pulses even between 0.2 nanoseconds and can operate in a fractional bandwidth of > 500 MHz, it is considerable system to use in location systems, especially for indoors where obstacles and other structures are causing problems on signals. However, because of its low frequency, it is hard to interference from outside. (Serpiello et al. 2017; Vasilyev et al. 2017; Alarifi et al. 2016; Mu & Yao 2010.) Validity of UWB-based LPS system for indoor measurements have been investigated. LPS system was able to track down players movement and speed in a typical error of 1.2–9.3 %, which is better when compared to GPS-based systems. The reliability of the research is increased by the fact that Vicon was the reference system used (Serpiello et al. 2017).

3.4 Associations of external and internal load

External loading is often associated with variables used to measure internal loading, such as heart rate monitoring, session Ratings of Perceived Exertion (sRPE), or training-impulse (TRIMP), and this combination has been used in several different sports already. (Cunniffe et al. 2009; DeMartini et al. 2011; Sobolewski 2020) In this case, the combined result of the external and internal load is the total load of the athlete. By monitoring external and internal loads, it is possible to monitor the total load of athletes, enabling preventive load regulation and thus prevention of possible strain-related injury (Drew & Finch 2016).

The connection between internal and external load has been studied extensively from the perspectives of various methods and study designs. It has been shown that mechanical, metabolic, and perceptual loading in sprint training can be monitored through together or in separated. For example, Jimenez-Reyes et al. (2016) investigated the relationship between internal and external load variables in the training of short sprint performances in sprinters. The research subjects were 9 male high-level sprinters, who performed 40 m sprints as long as they suffered more than 3 % loss in time from the fastest recorded time twice in a row. In 10 seconds after each performance, sprinters were asked sRPE, and performed 3 CMJ after verbal sRPE, and mean value was calculated as a result of CMJ. After one minute of each execution, lactate samples were taken. Recovery between performances was 4 minutes. (Jimenez-Reyes et al. 2016.)

It turned out that every variable, whether it was internal or external, was in association with each other. Statistical significances varied between variables, but each variable nevertheless had some degree of connection with each other. For example, blood lactate concentration had strong connections with the number of sprints, CMJ jump height decrease and sRPE ($r = 0.87$, $r = 0.96$ and $r = 0.87$), respectively. (Jimenez-Reyes et al. 2016.) It is important to understand that the connections between variables vary in strength. When comparing the values of internal and external load variables, statistical differences can be observed, which indicate how strongly the variables are connected to each other. For example, McLaren et al. (2017)'s meta-analysis from associations of internal and external load found, that the external load variable total distance running (TD) and the internal load variable session rating of perceived exertion training load (sRPE-TL) were most strongly connected to each other (r = 0.79), while correspondingly, the distance covered in very high speed variable showed a very small relationship with sRPE-TL or TRIMP (r = 0.25 and r = 0.17), respectively (McLaren et al. 2017).

The connection of internal and external load to sports performance has also been studied, but depending on the study, the results differ to some extent. However, consistency can be found, for example, between two external load variables, as distance traveled, and distance covered in very high-speed seem to be strongly connected. (Fox et al. 2018.) The claim is also supported by Rampanini et al. (2007), when they conducted a study with soccer players, where the results indicated the same way. In addition, the study noticed that there was a connection between the distance traveled and the highest speed value achieved in the test, so it can be concluded that athletes who move in high-speed ranges also traveled the most on the field (Rampanini et al. 2007).

4 DIFFERENCES IN MATCHES AND PERIODS AT DIFFERENT LEVELS

As mentioned previously, floorball lacks in the number of studies focused on the physiological match performance. Therefore, differences in matches and periods in different levels needs to be examined through other sports that may be close to the physiological demands of floorball. Futsal, basketball, and handball were selected as the sports for comparison, due to the variation in the intensity of the sports within the match, as well as the amount of distance traveled during the match.

In futsal, significant differences have been noticed in the comparison between halves. The number of high-intensity performances by a player decreased when first and second half were compared. In addition, the average distance traveled per minute was decreasing towards the end of the match. However, there do not seem to be any differences between playing positions, and the load during the match is evenly distributed across all positions. (Bueno et al. 2014.) Although the intensity decreases in futsal, the duration of sprints seems to increase towards the end of the match. Correspondingly, however, the recovery time after sprints increases at the same time. (Caetano et al. 2015.) An important factor in the results is the thresholds of the different speed ranges, which enable the sprint time to be measured even when the actual speed decreases.

Álvarez et al. (2009) compared the differences in the levels of series with adults in aerobic fitness. They compared professional elite male level futsal players to semi-professional male futsal players, with the purpose of finding out the importance of aerobic fitness between levels. It turned out that maximal oxygen uptake was significantly higher in professional elite players than in semi-professional players (62.9 ± 5.3 and 55.2 ± 5.7 ml/kg/min, $p < 0.01$), showing that the measure of aerobic fitness can be a variable that makes a difference in futsal between different levels. Authors also stated that 60 ml/kg/min may be a distinguishing factor for an athlete to be an elite level futsal player. (Álvarez et al. 2009.)

In basketball, even within the level, it has been noticed that there are statistically significant player-specific differences. Abdelkrim et al. (2010a) studied the differences between international-level players and national-level players and noticed that an international-level player performs more high-intensity match actions during the game compared to a national-level player. In blood lactate concentration, there were also significant differences between groups. The blood lactate concentration of the international-level players was 6.60 ± 1.22 mmol/l at halftime, and 5.65 ± 1.21 mmol/l at the end of the match, while they were 5.66 ± 1.19 and 4.43 ± 1.43 mmol/l respectively for the national-level player ($p < 0.05$). International-level players spent more time in maximal (> 95 % of HR_{max}) and high-intensity (85–95 % of HR_{max}) zone. International players time spent in > 95 % of HR_{max} were 17.8 %, when national-level players resulted 15.2 % ($p < 0.01$), and time spent in 85–95 % of HR_{max} resulted 59.1 vs. 54.4 % ($p < 0.05$), respectively. (Abdelkrim et al. 2010a.)

In Abdelkrim et al. (2010) study, the amount of low-intensity movement of international-level players was also higher than that of national-level players. This finding is in line with Castagna et al. (2008) study, where authors discovered difference of active and passive recovery to RSA. Castagna et al. (2008) conducted a study with young basketball players (age 16.8 ± 1.2 years), where the players performed a 10 x 15 m RSA test, using either active 50 % of maximal aerobic speed or standing still to recover between repetitions. Players who recovered passively were able to complete the test with a lower fatigue index, and their total sprint time was lower. Correspondingly, there were no differences in lactate levels. (Castagna et al. 2008.) In contrast to futsal, in basketball there are differences between the playing positions in terms of total distance traveled, but depending on the study, the differences vary so much that it is not possible to draw direct conclusions (Stojanović et al. 2017).

Similar differences within the level can also be seen in handball. Nikolaidis and Ingebrigtsen (2013) compared the physiological performances and anthropometrics of players from teams that played at the same league level and noticed that the physiological and anthropometric differences of the players from the eight ranked team were statistically significant compared to the players from the first and second ranked teams. In anthropometric measurements, the average height of the players in the eighth-ranked team was clearly shorter compared to the first two teams (179.0 ± 4.7 vs. 185.1 ± 6.5 and 188.2 ± 6.1, $p = 0.000$). In addition, the eighth ranked team had lower fat free mass values compared to the other two teams (66.4 ± 5.5 vs. 72.8 ± 5.3 and 71.7 ± 6.2, $p = 0.012$). In the physiological measurements, the biggest difference was in the mean power (30 s Bosco) test, where the results differed according to the p-value result of 0.000. In different jumping tests, the differences were statistically significant in SJ $p = 0.015$, CMJ $p = 0.029$ and CMJarm $p = 0.026$. (Nikolaidis and Ingebrigtsen 2013.)

Differences between players at different ages can also be seen in handball. For example, Chelly et al. (2011) study results showed that adolescent male handball players aged 15.1 ± 0.6 (n = 18) travelled an average of 1777 ± 264 m during a match, but in Font et al. (2021) study, the distance traveled by adults (26.6 ± 6.3 years) was on average 3666 m during the match, regardless of the playing position. However, it should be noted that in handball there is no limit to the number of substitutions during a match, so playing time can influence the total distance traveled during the match. In Chelly et al. (2011) study, the playing time of younger players is not reported, so the comparison of the study results is not necessarily completely possible. The assumption is supported by the fact that when participating in the game, the player's movement on the field is based on high-intensity movement, which can be verified through the mean HR value (83 to 85% of HR_{max}), although about 66% of the movement during the game is standing or jogging (Põvoas et al. 2014).

5 RESEARCH QUESTIONS AND HYPOTHESIS

No similar kind of studies have been conducted on the floorball before. In the past, there have been few position-specific comparisons, but current technology has not been used in these studies. In general, sport-specific studies of different playing positions comparisons have been conducted, and recent studies have also taken advantage of current technology. However, there is relatively little previous research data on comparisons between different series of levels.

For these reasons, the purpose of the study is to investigate the differences and connections in competitive floorball match between levels period-by-period and game in general. Different overall load variables were divided into two (internal and external) variables. Because the lack of recent studies, comparative studies have been searched from other sports.

Research question 1: Does the total match load differ between levels?

Hypothesis 1: Yes. There are differences especially in external load because higher level of play requires a higher level of intensity, which can occur in total distance travelled.

Argument: References can be found in several different sports. Elite male basketball players seem to produce more intermittent external loading when compared to sub-elite male basketball players. Although sub-elite players moved more in the high-end zone, elite players had more variance in their movement, which resulted also higher total distance travelled during the game. (Scanlan et al. 2011.) However, when comparing different sports with each other, discrepancy is seen on the comparison between stages. In Chelly et al. (2011) study, male junior handball players (age 15.1 ± 0.6) travelled 1777 ± 264 m per match, but when Font et al. (2021) discovered elite male handball player differences between playing positions, authors found that each playing position had larger values, despite there were also significant differences in playing positions between male elite handball players (center backs 4040 ± 1007 m, wings 3903 ± 1224 m, backs 3571 ± 864 m and line players 3149 ± 630 m).

Research question 2: Are there differences in match load between periods in different levels?

Hypothesis 2: Yes. Differences between periods can be seen between periods and between levels, but reasons may vary in between levels.

Argument: Abdelkrim et al. (2010a) found that the active participation of international-level players in the game was higher than that of national-level players in all four quarters. In addition, the frequency of sprints and high-intensity play were significantly higher in international-level players, which affected the time spent in the high-intensity zone (Abdelkrim et al. 2010a). On the other hand, variation in match load can be explained with age and physiological development. Abdelkrim et al. (2010b) compared different ages and playing positions between U18, U20 and Men, and found that especially physiological abilities develop when players get older. In addition, Williams et al. (2021) found that loading differences may vary because of the playing positions in basketball, since the backcourt players seems to have more involvement both in training and in matches. Correspondingly, frontcourt players have more variance in physiological loading between matches and training sessions. (Williams et al. 2021.) These results can also be attributed to tactical choices in matches and training sessions. Bueno et al. (2018) investigated the role of the tactical side in player movements in defensive and offensive situations. Based on the results, the subjects in the U15 group covered a smaller part of the playing area in terms of surface area when they were an offensive team (with ball possession) compared to the U18 and PRO groups. This then refers to smaller distance to other players, as well as less need to move during the game. Similarly, in a defensive situation (without ball possession), the distances of the U18 group to their own players were greater than those of the U15 and PRO groups, suggesting higher amounts in terms of distance traveled, respectively, from a tactical point of view. (Bueno et al. 2018.) Póvoas et al. (2014) had also similar results from handball. Variation between physiological demands varied between depending on positions, but also in overall load between halves. In handball match, players seem to spend less time in intensities >80 % of HRmax in second halve compared to first.

Research question 3: Is there a relationship between internal and external loads on every level?

Hypothesis 3: Yes. Different variables between internal and external loading are in connection with each other.

Argument: Previous studies have shown relationship between internal and external load variables. In particular, the connections between distance traveled and internal load variables and intensity have been shown to be strong (McLaren et al. 2017). It has also been found that CK production may be due in particular to acceleration-type performances (Vanrenterghem et al. 2017), although the greatest production increases when eccentric muscle work is heavily included (Brancaccio et al. 2007). Similar findings have also reported in Wedin & Henriksson's (2014) study, where they investigated muscle damages caused by floorball match.

6 METHODS

6.1 Subjects

A total of 24 Finnish floorball players from three different levels participated in this study. Total of 8 subjects played at the highest level of the Finnish men's league (F-League), 8 played at the highest level of the oldest youth (U21) and 8 played at the highest level of the second oldest youth (U18). Total number of analyzed games was 27, which distributed as: 12 men’s games, 6 U21 games and 9 U18 games. Games analyzed for the study were played during the 2021-2022 season. All individuals in the study were either defenders, wingers or centers. Goalkeepers did not participate in the study. The results obtained were pre-numerically anonymized to correspond to each individual subject. The identity of the individual subject could not be inferred from the results processed. The results were subsequently calculated as means and standard deviations to provide a more accurate description of the results from each level.

TABLE 4. Description of subjects.

SUBJECTS	n	Age (mean)	Weight (kg)	Height (cm)	Games (qty)	Measurements (qty)
U18 all	8	16.5 ± 0.3	69.1 ± 5.7	180.4 ± 6.0	9	47
U18 defender	3	16.4 ± 0.4	65.8 ± 4.7	178.0 ± 3.5	8	20
U18 winger	3	16.5 ± 0.4	70.0 ± 3.9	183.0 ± 9.2	9	21
U18 center	2	16.5 ± 0.3	72.5 ± 9.8	180.0 ± 4.2	5	6
U21 all	8	18.0 ± 0.6	68.1 ± 1.6	178.4 ± 4.2	6	23
U21 defender	3	17.6 ± 0.1	69.4 ± 0.8	180.7 ± 4.0	5	8
U21 winger	2	18.8 ± 0.4	67.4 ± 2.1	179.5 ± 0.7	5	6
U21 center	3	18.0 ± 0.4	66.9 ± 0.5	175.3 ± 4.7	6	9
Men all	8	25.8 ± 6.2	79.3 ± 6.4	181.6 ± 7.5	12	45
Men defender	2	31.3 ± 12.3	76.6 ± 1.2	178.5 ± 3.5	9	13
Men winger	3	23.7 ± 0.7	84.2 ± 6.8	187.0 ± 8.9	12	20
Men center	3	24.1 ± 4.2	76.3 ± 6.4	178.3 ± 6.4	8	12

6.2 Study design

The study was conducted in official floorball matches. Games have been played in three different series of levels (U18, U21 and men’s national level). The U18, U21 and men's games were played in the regular season matches of the Finnish Floorball Association in the season 2021-2022. This study was part of larger project *Salibandyn fyysinen lajianalyysi*. which was commissioned by Finnish Floorball Federation and executed by Marko Haverinen (Varala Sports Institute) and Elisa Hakamäki (Eerikkilä Sports Institute). All the results and data used in this study are from measurements done in the previously mentioned project.

6.3 Measurements

GPS-based Polar® Team Pro (Polar Electro, Kempele, Finland) system for in-match load was used to measure internal and external load. Team Pro sensor has integrated GPS with 10 Hz and MEMS motion sensor 200 Hz, including 3D accelerometer, gyroscope and magnetometer installed. The sensors were attached to the sternum with a heart rate belt (Polar Electro, Kempele Finland). Subjects had the opportunity to detach their heart rate belt at any time during the match if they felt so. Results were collected for in-game workload. Recording lasted from the start until the end of the match. Time between periods were filtered from the results afterwards. Data collection is presented in the figure 2.

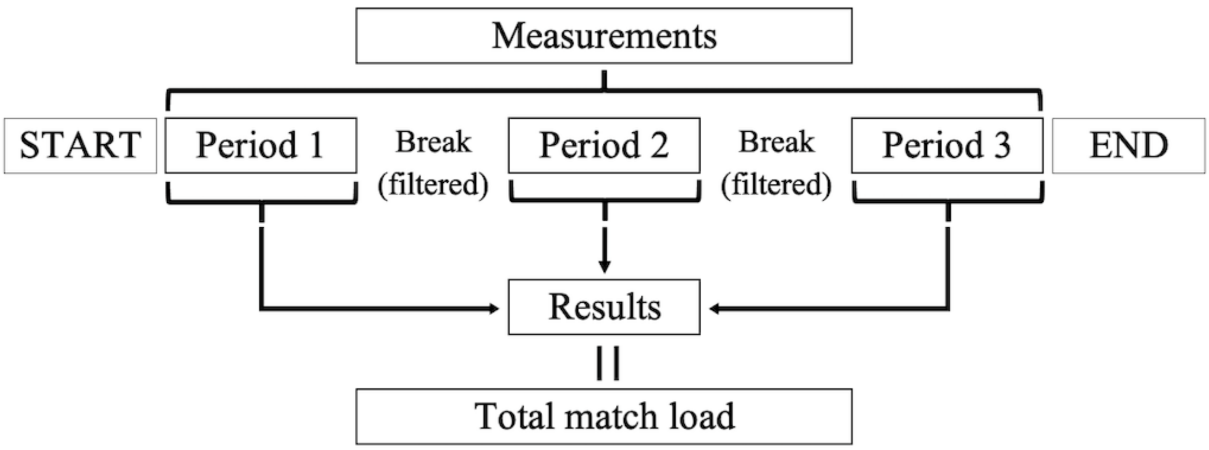

FIGURE 2. Data collected from the match and compilation of the total match load.

6.3.1 Speed measurements

Speed zones. Each sample (0.1s) spent in the speed zone is included in the distance calculation per zone. The zone-specific distance is obtained from two consecutive samples (10 Hz sampling frequency) using the following formula: current distance measurement result minus previous distance measurement result. Speed zones are presented in table 5, threshold values are presented as km/h and m/s^2.

TABLE 5. Velocity zones in floorball (adapted from Sweeting et al. 2017; Dwyer et al. 2012).

ZONE	DESCRIPTOR	INTENSITY	THRESHOLD	
1	Very slow-speed running	**Low-intensity running**	3.00 - < 10.00	0.83 - < 2.78
2	Slow-speed running		≥ 10.00 - < 14.00	≥ 2.78 - < 3.89
3	Moderate-speed running	**Moderate-intensity running**	≥ 14.00 - < 18.00	≥ 3.89 - < 5.00
4	High-speed running	**High-intensity running**	≥ 18.00 - < 22.00	≥ 5.00 - < 6.11
5	Very high-speed running		≥ 22.00	≥ 6.11
	Sprints	**Maximal running**	≥ 22.00	≥ 6.11

Sprints. When going beyond the desired limit value (0.1 s run), one sprint repetition is added to the calculation. The run is calculated from the peak speed reading and a 0.1 s run over the limit is sufficient to achieve sprint performance. Limit was set to >22 km/h.

Acceleration and deceleration. When accelerating / decelerating above a certain limit range (0.1 s run; 10Hz sampling frequency), one repetition is added to that acceleration / deceleration zone. The run is calculated from the peak acceleration and deceleration measurements and a run of 0.1 s is sufficient to provide a repetition for that zone. In that time, no performance is calculated for the other acceleration / deceleration zones during the change in acceleration. The next review of the accelerations begins after one visit to the deceleration side after the acceleration, at which point the evaluation of the accelerations begins again. Correspondingly, the next review of deceleration begins after one visit to the acceleration side after deceleration, at which point the evaluation of deceleration begins again. Accelerations and decelerations are presented in table 6.

TABLE 6. Accelerations and decelerations in floorball (adapted from Russell et al. 2016).

ZONE	DESCRIPTOR	ACC / DEC	THRESHOLD
4	Maximal acceleration		≥ 3.00 - < 50.00
3	High acceleration	**Accelerations**	≥ 2.00 - < 3.00
2	Intermediate acceleration		≥ 1.00 - < 2.00
1	Low acceleration		> 0.50 - < 1.00
1	Low deceleration		< -0.50 - < -1.00
2	Intermediate deceleration	**Decelerations**	≤ -1.00 - < -2.00
3	High deceleration		≤ -2.00 - < -3.00
4	Maximal deceleration		≤ -3.00 - < -50.00

6.4 Inclusion criteria

Matches and players included in this study were included if they passed the two-phase inclusion criteria'. In phase 1, matches that included to the study needed to meet with the following criteria: (1) Competitive match with high demand of overall floorball (defined by group of experts from Finnish Floorball Federation), (2) closer to the end than the beginning of the regular season, and (3) goal difference between teams was three or less at the start of the third period.

After phase 1, measurements were collected and analyzed individually. Then phase 2 of inclusion criteria was used, and individuals that passed were included to the final analysis. Criteria in phase 2 were: (1) only regular match time (overtime or penalty shootouts were not included), (2) player has played the whole match, and (3) player has played at least four shifts in each period.

After inclusion criteria, all variable results were calculated using either sum or average as values accumulated from matches. Maximum speed was marked individually as the highest speed value achieved during the match. Average was calculated from each subject who performed in more than one match. Finally, the results were further separated into the following: U18 Game, U18 1.period, U18 2.period, U18 3.period, U21 Game, U21 1.period, U21 2.period, U21 3.period, Men Game, Men 1.period, Men 2.period, and Men 3.period.

6.5 Statistical analysis

Statistical analyses were made with IBM SPSS Statistics 27- software (International Business Machines Corp, New York, United States) and Microsoft Excel Version 16.58 (Microsoft Corporation, Redmond, United States). Because of the small sample size, non-parametric tests were used to analyze results. Kruskal-Wallis test was used to analyze differences between levels and in differences between periods of levels. Friedman's test was used to search for correlations between internal and external game-time loading.

7 RESULTS

7.1 The results of total match load variables

Significant difference between levels was found in the calorie consumption during the match ($p = 0.005$, table 7). No significant differences resulted in any other variable ($p > 0.05$). Calorie consumption differences was also seen on every period between levels (figure 3).

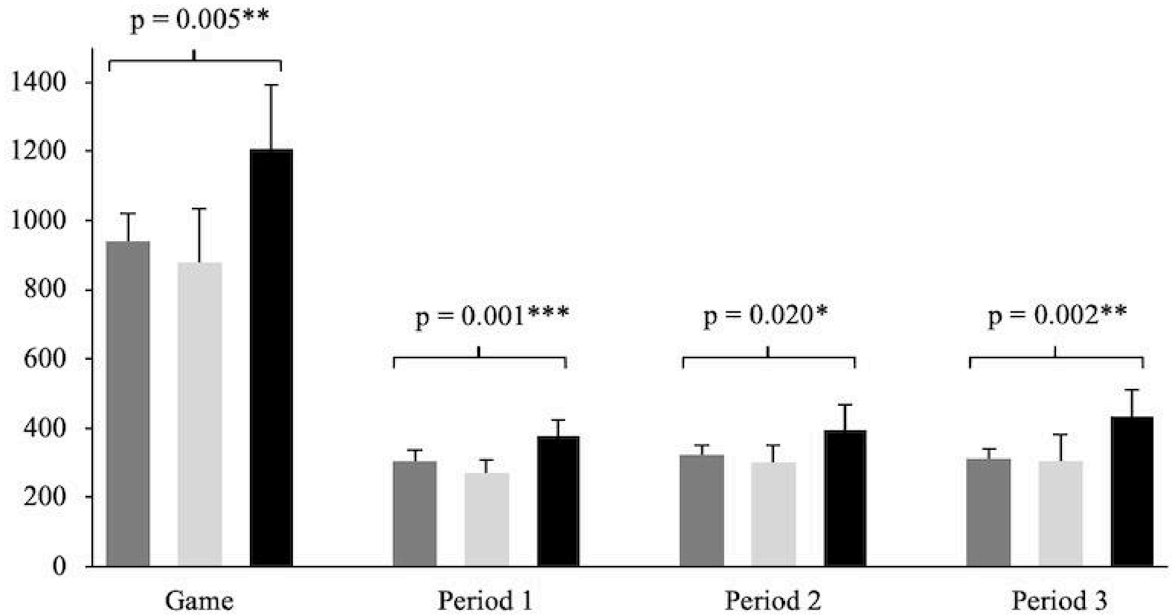

FIGURE 3. Calorie consumption between periods and levels. Darker grey is presenting U18, lighter grey is presenting U21, and black bar is presenting men. $p < 0.001$***.

Symptomatic differences ($p < 0.1$) were seen in 80-89 % /HRmax (U18 = 18:10 ± 04:12, U21 = 16:24 ± 05:35, Men = 22:12 ± 04:35, $p = 0.096$) and in distance traveled >22.00 km/h (U18 = 100 ± 60, U21 = 174 ± 137, Men = 202 ± 86, $p = 0.060$).

TABLE 7. Total match load results between stages.

VARIABLES	U18 GAME Mean ± SD	n	U21 GAME Mean ± SD	n	MEN GAME Mean ± SD	n	p-value
Shifts (number / game)	21.9 ± 1.9	8	21.1 ± 2.7	8	23.6 ± 2.7	8	0.111
HRmin (bpm)	109.8 ± 10.1		102.0 ± 12.5		106.8 ± 9.5		0.368
HRavg (bpm)	149.2 ± 9.5		143.4 ± 10.4		147.6 ± 8.5		0.573
HRmax (bpm)	192.4 ± 7.2		187.2 ± 7.8		189.7 ± 7.1		0.424
HRmin (%)	52.6 ± 3.2		49.5 ± 5.6		53.0 ± 3.8		0.281
HRavg (%)	71.6 ± 3.1		69.4 ± 5.6		73.2 ± 3.8		0.208
HRmax (%)	92.4 ± 4.1		90.5 ± 4.7		94.2 ± 1.8		0.131
50–59%/HRmax (min:ss)	13:58 ± 09:36		19:01 ± 13:24		10:42 ± 08:49		0.406
60–69%/HRmax (min:ss)	33:29 ± 07:42		28:54 ± 05:56		29:46 ± 05:47		0.305
70–79%/HRmax (min:ss)	19:12 ± 05:40		20:15 ± 06:10		21:53 ± 05:00		0.493
80–89%/HRmax (min:ss)	18:10 ± 04:12		16:24 ± 05:35		22:12 ± 04:35		0.096
90–100%/HRmax (min:ss)	07:20 ± 06:34		04:39 ± 08:15		08:04 ± 03:25		0.113
Total Distance (m)	4023 ± 599		4085 ± 934		4389 ± 891		0.605
Average distance (m/min)	43.4 ± 6.3		44.3 ± 10.5		46.8 ± 8.3		0.728
Maximal speed (km/h)	26.8 ± 2.4		27.3 ± 1.8		27.3 ± 1.2		0.203
Average speed (km/h)	2.6 ± 0.4		2.7 ± 0.6		2.8 ± 0.6		0.761
Sprints (qty.)	11.2 ± 5.7		17.6 ± 11.6		19.8 ± 7.8		0.105
Distance in zone 1 (3.00 - 9.99 km/h) (m)	2188 ± 336		2032 ± 359		2263 ± 521		0.578
Distance in zone 2 (10.00 - 13.99 km/h) (m)	876 ± 191		892 ± 297		893 ± 283		0.993
Distance in zone 3 (14.00 - 17.99 km/h) (m)	530 ± 133		605 ± 226		619 ± 142		0.573
Distance in zone 4 (18.00 - 21.99 km/h) (m)	224 ± 68		285 ± 120		302 ± 142		0.203
Distance in zone 5 (22.00- km/h) (m)	100 ± 60		174 ± 137		202 ± 86		0.060
Calories (kcal)	940 ± 79		877 ± 156		1206 ± 187		0.005**
Accelerations 0.50 - 0.99 m/s² (qty.)	193.3 ± 22.8		170.2 ± 20.9		193.2 ± 30.9		0.145
Accelerations 1.00 - 1.99 m/s² (qty.)	225.0 ± 42.6		206.2 ± 30.7		227.6 ± 61.5		0.675
Accelerations 2.00 - 2.99 m/s² (qty.)	78.3 ± 14.9		80.5 ± 28.8		87.3 ± 18.0		0.406
Accelerations 3.00 - 50.00 m/s² (qty.)	0.5 ± 0.6		1.1 ± 1.4		1.3 ± 1.0		0.204
Decelerations –50.00 - –3.00 m/s² (qty.)	17.7 ± 4.8		17.0 ± 8.4		22.1 ± 8.1		0.294
Decelerations –2.99 - –2.00 m/s² (qty.)	59.0 ± 12.9		61.1 ± 15.8		70.1 ± 14.2		0.251
Decelerations –1.99 - –1.00 m/s² (qty.)	249.1 ± 37.7		228.7 ± 32.3		241.7 ± 46.7		0.553
Decelerations –0.99 - –0.50 m/s² (qty.)	212.4 ± 36.7		195.3 ± 34.6		208.9 ± 43.8		0.608

SD = standard deviation. HRmin = minimum heart rate. HRavg = average heart rate. HRmax = maximum heart rate. %HRmax = time spent in heart rate zone of maximum heart rate. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

In total match loading between accelerations and decelerations, significant difference was found between accelerations in area 3.00 – 50.00 m/s^2 and decelerations in area –50.00 - –3.00 m/s^2 variables in every level. U18 level resulted 0.5 ± 0.6, U21 1.1 ± 1.4 and Men 1.3 ± 1.0 means in match-time performance in acceleration in area 3.00 – 50.00 m/s^2 per match, and decelerations in area –50.00 - –3.00 m/s^2 were U18 = 17.7 ± 4.8, U21 = 17.0 ± 8.4 and Men 22.1 ± 8.1 per match, statistical difference between variables p = 0.005 (figure 4).

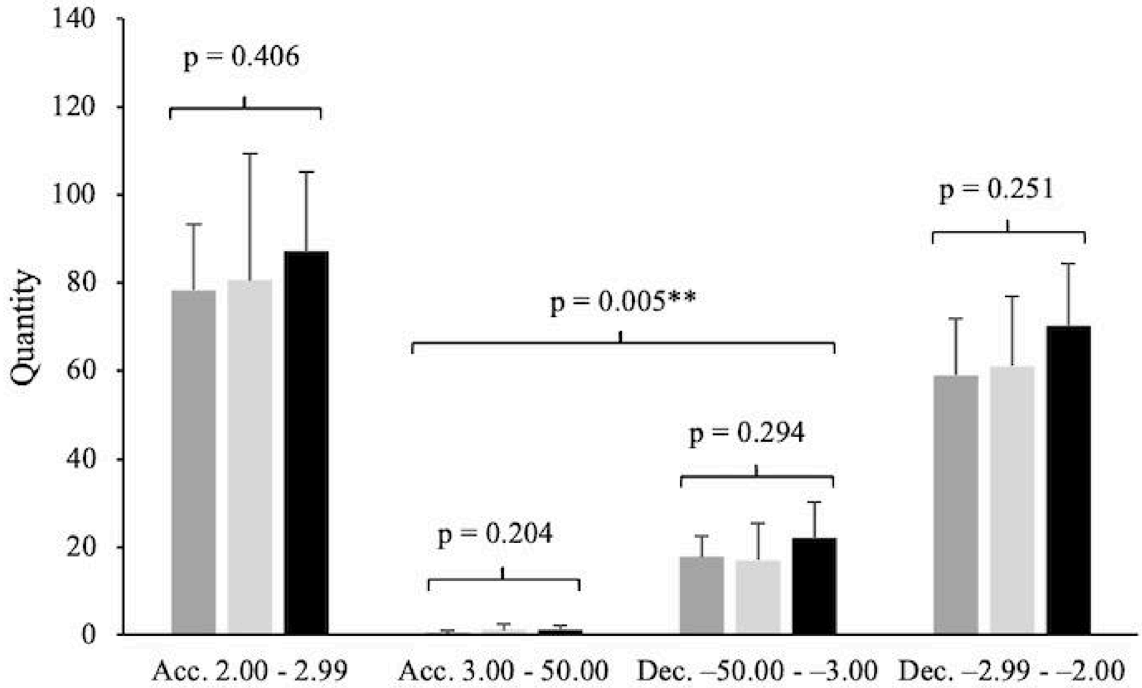

FIGURE 4. Match-time means in highest value zones in acceleration and deceleration. U18 is presented in darker grey, U21 lighter grey and men in black bar. Differences between levels have analyzed with non-parametric Kruskal-Wallis test. Differences between acceleration and deceleration variables have been analyzed with Friedman's test. $p < 0.010$**.

7.2 External load variation between periods of levels

External load differences in the first period are presented in table 8. Variables related to external load of the first period showed statistical differences in two different variables. Number of shifts during first period was higher in Men's games, recording average number of shifts at 7.9 ± 0.5 per first period while U18 and U21 subjects recorded 7.4 ± 0.5 and 6.7 ± 0.7 shifts per first period ($p = 0.010$). Quantity of accelerations at 0.50 – 0.99 m/s^2 showed also statistical difference between levels: U18 60.5 ± 5.9, U21 50.3 ± 6.8, Men 60.5 ± 7.2 ($p = 0.013$). Symptomatic difference ($p < 0.1$) was found between levels on maximal speed (25.4 ± 1.6 vs 27.2 ± 1.7 vs 26.8 ± 0.9 km/h, $p = 0.056$), Distance in zone 5 (34 ± 20 vs 50 ± 31 vs 66 ± 32, $p = 0.096$), in Accelerations 1.00 – 1.99 m/s^2 (74.8 ± 9.0 vs 60.0 ± 14.2 vs 71.1 ± 11.9, $p = 0.096$), and in Decelerations –1.99 - –1.00 m/s^2 (80.1 ± 8.7 vs 66.3 ± 13.5 vs 74.8 ± 8.5, $p = 0.093$) (U18 vs U21 vs Men, respectively).

TABLE 8. External load variable differences in the first period.

	U18 PERIOD 1		U21 PERIOD 1		MEN PERIOD 1		
VARIABLES	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	p-value[a]
		8		8		8	
Shifts (number / game)	7.4 ± 0.5		6.7 ± 0.7		7.9 ± 0.5		**0.010****
Total Distance (m)	1341 ± 153		1254 ± 323		1372 ± 196		0.512
Average distance (m/min)	46 ± 5		44 ± 12		46 ± 7		0.761
Maximal speed (km/h)	25.4 ± 1.6		27.2 ± 1.7		26.8 ± 0.9		0.056
Average speed (km/h)	2.8 ± 0.3		2.7 ± 0.7		2.8 ± 0.4		0.763
Sprints (qty.)	3.6 ± 1.9		5.4 ± 3.4		6.5 ± 2.9		0.125
Distance in zone 1 (3.00 - 9.99 km/h) (m)	700 ± 59		604 ± 121		679 ± 81		0.185
Distance in zone 2 (10.00 - 13.99 km/h) (m)	307 ± 64		289 ± 121		285 ± 78		0.829
Distance in zone 3 (14.00 - 17.99 km/h) (m)	188 ± 57		200 ± 86		199 ± 55		0.968
Distance in zone 4 (18.00 - 21.99 km/h) (m)	80 ± 33		85 ± 37		91 ± 34		0.763
Distance in zone 5 (22.00- km/h) (m)	34 ± 20		50 ± 31		66 ± 32		0.096
Accelerations 0.50 - 0.99 m/s² (qty.)	60.5 ± 5.9		50.3 ± 6.8		60.5 ± 7.2		**0.013***
Accelerations 1.00 - 1.99 m/s² (qty.)	74.8 ± 9.0		60.0 ± 14.2		71.1 ± 11.9		0.096
Accelerations 2.00 - 2.99 m/s² (qty.)	26.1 ± 5.0		26.1 ± 8.6		28.4 ± 6.5		0.602
Accelerations 3.00 - 50.00 m/s² (qty.)	0.2 ± 0.3		0.3 ± 0.4		0.4 ± 0.3		0.283
Decelerations –50.00 - –3.00 m/s² (qty.)	6.5 ± 1.9		5.2 ± 2.9		6.9 ± 3.1		0.454
Decelerations –2.99 - –2.00 m/s² (qty.)	19.5 ± 3.7		19.8 ± 5.2		23.2 ± 3.8		0.195
Decelerations –1.99 - –1.00 m/s² (qty.)	80.1 ± 8.7		66.3 ± 13.5		74.8 ± 8.5		0.093
Decelerations –0.99 - –0.50 m/s² (qty.)	66.0 ± 9.4		59.5 ± 13.8		65.9 ± 9.1		0.508

a = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

Differences in the second period are presented in the table 9. No statistically significant differences were found in the second period between levels, but maximum speed (U18 25.9 ± 2.4, U21 26.2 ± 2.5, Men 26.8 ± 0.6 km/h, p = 0.064) and distance in zone 5 (U18 34 ± 24, U21 50 ± 45, Men 66 ± 27 m, p = 0.072) showed symptomatic difference.

TABLE 9. External load variable differences in the second period.

	U18 PERIOD 2		U21 PERIOD 2		MEN PERIOD 2		
VARIABLES	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	p-value[b]
		8		8		8	
Shifts (number / game)	6.9 ± 0.6		7.1 ± 0.8		7.5 ± 1.1		0.615
Total Distance (m)	1361 ± 161		1428 ± 241		1423 ± 338		0.887
Average distance (m/min)	42 ± 5		46 ± 8		47 ± 9		0.578
Maximal speed (km/h)	25.9 ± 2.4		26.2 ± 2.5		26.8 ± 0.6		0.064
Average speed (km/h)	2.5 ± 0.3		2.8 ± 0.5		2.8 ± 0.5		0.686
Sprints (qty.)	3.7 ± 2.4		5.8 ± 3.9		6.5 ± 2.7		0.150
Distance in zone 1 (3.00 - 9.99 km/h) (m)	762 ± 95		742 ± 99		731 ± 213		0.590
Distance in zone 2 (10.00 - 13.99 km/h) (m)	277 ± 55		307 ± 85		288 ± 102		0.797
Distance in zone 3 (14.00 - 17.99 km/h) (m)	174 ± 41		194 ± 69		199 ± 43		0.581
Distance in zone 4 (18.00 - 21.99 km/h) (m)	77 ± 23		99 ± 44		103 ± 36		0.240
Distance in zone 5 (22.00- km/h) (m)	34 ± 24		50 ± 45		66 ± 27		0.072
Accelerations 0.50 - 0.99 m/s² (qty.)	66.6 ± 5.7		61.5 ± 7.4		63.3 ± 13.6		0.339
Accelerations 1.00 - 1.99 m/s² (qty.)	73.9 ± 14.9		73.2 ± 8.0		71.5 ± 23.2		0.573
Accelerations 2.00 - 2.99 m/s² (qty.)	26.7 ± 4.9		27.0 ± 8.3		28.5 ± 5.9		0.859
Accelerations 3.00 - 50.00 m/s² (qty.)	0.2 ± 0.1		0.5 ± 1.0		0.5 ± 0.5		0.291
Decelerations –50.00 - –3.00 m/s² (qty.)	5.6 ± 1.4		5.9 ± 2.9		7.5 ± 2.7		0.436
Decelerations –2.99 - –2.00 m/s² (qty.)	19.9 ± 4.0		20.4 ± 4.9		22.8 ± 5.5		0.665
Decelerations –1.99 - –1.00 m/s² (qty.)	85.8 ± 10.0		82.5 ± 10.3		76.5 ± 16.4		0.203
Decelerations –0.99 - –0.50 m/s² (qty.)	71.9 ± 9.3		70.8 ± 9.7		67.0 ± 18.4		0.309

b = differences between stages have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. p < 0.05*, p < 0.01** and p < 0.001***.

Results from the third period are shown in the table 10. Differences arose especially in distances travelled in different speed zones, but only distance in zone 4 resulted statistical difference (U18 67 ± 15, U21 101 ± 56, Men 107 ± 33 m, p = 0.030). Symptomatic differences (p < 0.1) were resulted in maximal speed (U18 25.3 ± 1.2, U21 26.6 ± 1.5, Men 27.1 ± 1.7 km/h, p = 0.056) and in distance in zone 5 (U18 32 ± 19, U21 74 ± 64, Men 70 ± 31 m, p = 0.064).

TABLE 10. External load variable differences in the third period.

VARIABLES	U18 PERIOD 3 Mean ± SD	n	U21 PERIOD 3 Mean ± SD	n	MEN PERIOD 3 Mean ± SD	n	p-value[c]
		8		8		8	
Shifts (number / game)	7.6 ± 1.0		7.3 ± 1.7		8.3 ± 1.4		0.130
Total Distance (m)	1321 ± 333		1403 ± 428		1594 ± 419		0.424
Average distance (m/min)	42 ± 11		43 ± 12		48 ± 11		0.493
Maximal speed (km/h)	25.3 ± 1.2		26.6 ± 1.5		27.1 ± 1.7		0.056
Average speed (km/h)	2.5 ± 0.6		2.6 ± 0.7		2.9 ± 0.7		0.493
Sprints (qty.)	3.8 ± 2.1		6.4 ± 4.8		6.8 ± 2.7		0.147
Distance in zone 1 (3.00 - 9.99 km/h) (m)	727 ± 206		686 ± 202		835 ± 237		0.357
Distance in zone 2 (10.00 - 13.99 km/h) (m)	292 ± 89		295 ± 98		320 ± 119		0.939
Distance in zone 3 (14.00 - 17.99 km/h) (m)	168 ± 45		211 ± 82		220 ± 60		0.203
Distance in zone 4 (18.00 - 21.99 km/h) (m)	67 ± 15		101 ± 56		107 ± 33		**0.030***
Distance in zone 5 (22.00- km/h) (m)	32 ± 19		74 ± 64		70 ± 31		0.064
Accelerations 0.50 - 0.99 m/s² (qty.)	66.2 ± 15.5		58.4 ± 9.6		69.3 ± 14.1		0.161
Accelerations 1.00 - 1.99 m/s² (qty.)	76.3 ± 22.7		73.0 ± 17.9		85.0 ± 27.4		0.793
Accelerations 2.00 - 2.99 m/s² (qty.)	25.5 ± 6.9		27.3 ± 13.1		30.3 ± 7.9		0.399
Accelerations 3.00 - 50.00 m/s² (qty.)	0.1 ± 0.2		0.3 ± 0.5		0.3 ± 0.3		0.553
Decelerations –50.00 - –3.00 m/s² (qty.)	5.6 ± 1.8		5.9 ± 3.2		7.8 ± 3.3		0.324
Decelerations –2.99 - –2.00 m/s² (qty.)	19.5 ± 7.0		20.9 ± 8.1		24.0 ± 5.9		0.438
Decelerations –1.99 - –1.00 m/s² (qty.)	82.5 ± 22.1		79.9 ± 18.6		90.4 ± 24.3		0.651
Decelerations –0.99 - –0.50 m/s² (qty.)	74.5 ± 20.9		65.0 ± 14.7		76.0 ± 19.8		0.471

c = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. p < 0.05*, p < 0.01** and p < 0.001***.

7.3 Internal load variation between periods of levels

Internal load differences in the first period are presented in table 11. Variables related to internal load of the first period showed statistical differences in two different variables. A Statistically significant difference was found in Calorie consumption (U18: 305 ± 31, U21: 270 ± 37, and Men 379 ± 44 kcal, p = 0.001) and Time in 80–89 % of HRmax (U18 05:55 ± 01:19, U21 05:18 ± 00:58, Men 06:59 ± 00:57 min:ss, p = 0.025).

TABLE 11. Internal load variable differences in the first period.

VARIABLES	U18 PERIOD 1 Mean ± SD	U21 PERIOD 1 Mean ± SD	MEN PERIOD 1 Mean ± SD	n	p-value[a]
				8	
HRmin (bpm)	108.0 ± 11.6	98.8 ± 11.5	103.0 ± 8.8		0.237
HRavg (bpm)	152.1 ± 9.2	143.8 ± 10.3	146.5 ± 8.5		0.380
HRmax (bpm)	193.4 ± 8.1	187.4 ± 9.3	190.1 ± 7.6		0.394
HRmin (%)	51.7 ± 4.0	48.0 ± 6.6	51.1 ± 3.4		0.369
HRavg (%)	73.0 ± 3.4	69.6 ± 5.1	72.7 ± 2.7		0.127
HRmax (%)	92.9 ± 4.7	90.6 ± 4.3	94.5 ± 2.0		0.090
50–59%/HRmax (min:ss)	03:10 ± 03:00	05:43 ± 03:23	04:02 ± 03:00		0.300
60–69%/HRmax (min:ss)	09:59 ± 02:15	09:02 ± 02:14	09:13 ± 01:55		0.416
70–79%/HRmax (min:ss)	06:59 ± 02:04	06:11 ± 01:45	06:46 ± 01:21		0.578
80–89%/HRmax (min:ss)	05:55 ± 01:19	05:18 ± 00:58	06:59 ± 00:57		**0.025**
90–100%/HRmax (min:ss)	02:46 ± 02:39	01:21 ± 02:33	02:27 ± 01:21		0.099
Calories (kcal)	305 ± 31	270 ± 37	379 ± 44		**0.001*** **

a = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. p < 0.05*, p < 0.01** and p < 0.001***.

Differences between levels in third period are presented in table 13. A statistical difference between levels was found in Calorie consumption (U18: 322 ± 28, U21: 301 ± 48, and Men: 395 ± 73 kcal, p = 0.020). Symptomatic difference (p < 0.1) was seen on time spent in 60–69 % of HRmax (U18 12:52 ± 03:20, U21 09:36 ± 01:14, and Men 10:34 ± 02:10 min:ss, p = 0.076). No other internal variable showed statistical difference in the second period.

TABLE 12. Internal load variable differences in the second period.

VARIABLES	U18 PERIOD 2 Mean ± SD	U21 PERIOD 2 Mean ± SD	MEN PERIOD 2 Mean ± SD	n	p-value[b]
				8	
HRmin (bpm)	111.1 ± 9.6	105.7 ± 12.9	110.0 ± 9.8		0.641
HRavg (bpm)	147.4 ± 9.3	144.8 ± 9.9	147.5 ± 9.1		0.867
HRmax (bpm)	191.9 ± 7.0	186.0 ± 8.4	188.9 ± 7.3		0.249
HRmin (%)	53.2 ± 3.4	51.2 ± 6.3	54.5 ± 4.0		0.402
HRavg (%)	70.7 ± 3.2	70.0 ± 5.6	73.1 ± 3.0		0.294
HRmax (%)	92.1 ± 4.1	90.0 ± 5.1	93.9 ± 1.6		0.155
50–59%/HRmax (min:ss)	05:06 ± 03:39	06:25 ± 04:53	02:55 ± 02:44		0.200
60–69%/HRmax (min:ss)	12:52 ± 03:20	09:36 ± 01:14	10:34 ± 02:10		0.076
70–79%/HRmax (min:ss)	06:14 ± 01:51	07:24 ± 02:23	06:50 ± 01:58		0.523
80–89%/HRmax (min:ss)	05:45 ± 01:18	05:35 ± 02:17	07:13 ± 01:47		0.270
90–100%/HRmax (min:ss)	02:17 ± 02:13	01:40 ± 02:40	02:33 ± 01:05		0.383
Calories (kcal)	322 ± 28	301 ± 48	395 ± 73		**0.020***

b = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

Results from the third period are shown in table 13. Calorie consumption was the only statistically significant difference in the third period between levels (U18 313 ±27, U21 306 ± 75, Men 432 ± 77 kcal, p = 0002). Symptomatic difference ($p < 0.1$) is seen on time spent in 90–100 % of HRmax (U18 02:16 ± 01:56, U21 01:39 ± 03:09, and Men 03:04 ± 01:26, p = 0.068). No other internal variable showed statistical difference between levels in third period.

TABLE 13. Internal load variable differences in the third period.

VARIABLES	U18 PERIOD 3 Mean ± SD	U21 PERIOD 3 Mean ± SD	MEN PERIOD 3 Mean ± SD	n	p-value[c]
				8	
HRmin (bpm)	110.2 ± 12.1	101.7 ± 16.5	107.5 ± 11.3		0.482
HRavg (bpm)	148.3 ± 10.9	141.7 ± 12.0	148.7 ± 8.8		0.444
HRmax (bpm)	191.8 ± 7.1	188.1 ± 7.1	190.0 ± 6.7		0.358
HRmin (%)	52.7 ± 4.0	49.2 ± 8.2	53.2 ± 4.8		0.493
HRavg (%)	71.0 ± 3.5	68.5 ± 6.5	73.8 ± 3.3		0.105
HRmax (%)	92.1 ± 3.8	91.1 ± 5.2	94.3 ± 2.0		0.244
50–59%/HRmax (min:ss)	05:42 ± 03:32	06:54 ± 05:34	03:46 ± 03:33		0.424
60–69%/HRmax (min:ss)	10:39 ± 02:38	10:15 ± 03:23	10:00 ± 02:51		0.686
70–79%/HRmax (min:ss)	06:00 ± 02:01	06:41 ± 02:24	08:18 ± 02:01		0.120
80–89%/HRmax (min:ss)	06:31 ± 01:51	05:31 ± 02:39	08:01 ± 02:08		0.223
90–100%/HRmax (min:ss)	02:16 ± 01:56	01:39 ± 03:09	03:04 ± 01:26		0.068
Calories (kcal)	313 ± 27	306 ± 75	432 ± 77		**0.002****

c = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

7.4 Differences within levels between periods

Statistically significant differences between periods in U18 level are presented in table 14. Significant differences were seen on HRavg ($p = 0.044$), HRavg % ($p = 0.044$), time spent in 50–59 % of HRmax ($p = 0.010$), time spent in 60–69 % of HRmax ($p = 0.002$), and in calorie consumption ($p = 0.044$) (period 1 vs period 2 vs period 3, respectively). All results can be seen on appendix 1.

TABLE 14. Differences within U18 level between periods.

VARIABLES	U18 PERIOD 1 Mean ± SD	U18 PERIOD 2 Mean ± SD	U18 PERIOD 3 Mean ± SD	n	p-value[a]
				8	
HRavg (bpm)	152.1 ± 9.2	147.4 ± 9.3	148.3 ± 10.9		**0.044***
HRavg (%)	73.0 ± 3.4	70.7 ± 3.2	71.0 ± 3.5		**0.044***
50–59%/HRmax (min:ss)	03:10 ± 03:00	05:06 ± 03:39	05:42 ± 03:32		**0.010****
60–69%/HRmax (min:ss)	09:59 ± 02:15	12:52 ± 03:20	10:39 ± 02:38		**0.002****
Calories (kcal)	305 ± 31	322 ± 28	313 ± 27		**0.044***

a = differences between periods have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

Statistically significant differences between periods in U21 level are presented in table 15. Differences were seen between periods in maximal speed ($p = 0.030$), distance in speedzone 1 ($p = 0.030$), distance in speedzone 5 ($p = 0.011$), calorie consumption ($p = 0.017$), and in accelerations 0.50 – 0.99 m/s^2 ($p = 0.002$) (period 1 vs period 2 vs period 3, respectively). All results can be seen in appendix 2.

TABLE 15. Differences within U21 level between periods.

VARIABLES	U21 PERIOD 1 Mean ± SD	U21 PERIOD 2 Mean ± SD	U21 PERIOD 3 Mean ± SD	n	p-value[b]
				8	
Maximal speed (km/h)	27.2 ± 1.7	26.2 ± 2.5	26.6 ± 1.5		**0.030***
Distance in zone 1 (3.00 - 9.99 km/h) (m)	604 ± 121	742 ± 99	686 ± 202		**0.030***
Distance in zone 5 (22.00- km/h) (m)	50 ± 31	50 ± 45	74 ± 64		**0.011***
Calories (kcal)	270 ± 37	301 ± 48	306 ± 75		**0.017***
Accelerations 0.50 - 0.99 m/s^2 (qty.)	50.3 ± 6.8	61.5 ± 7.4	58.4 ± 9.6		**0.002****

b = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

Statistically significant differences between periods in Mens' level are presented in table 16. Differences were seen between periods in number of shifts ($p = 0.014$), HRmin ($p = 0.008$), HRmin % ($p = 0.024$), distance in speedzone 1 ($p = 0.010$), distance in speedzone 4 ($p = 0.030$), calorie consumption ($p = 0.030$), accelerations 1.00 – 1.99 m/s^2 ($p = 0.034$), and decelerations –1.99 - –1.00 m/s^2 ($p = 0.034$) (period 1 vs period 2 vs period 3, respectively). All the results can be seen on appendix 3.

TABLE 16. Differences within Men's level between periods.

VARIABLES	MEN PERIOD 1 Mean ± SD	MEN PERIOD 2 Mean ± SD	MEN PERIOD 3 Mean ± SD	n	p-value[c]
				8	
Shifts (qty.)	7.9 ± 0.5	7.5 ± 1.1	8.3 ± 1.4		**0.014***
HRmin (bpm)	103.0 ± 8.8	110.0 ± 9.8	107.5 ± 11.3		**0.008****
HRmin (%)	51.1 ± 3.4	54.5 ± 4.0	53.2 ± 4.8		**0.024***
Distance in zone 1 (3.00 - 9.99 km/h) (m)	679 ± 81	731 ± 213	835 ± 237		**0.010****
Distance in zone 4 (18.00 - 21.99 km/h) (m)	91 ± 34	103 ± 36	107 ± 33		**0.030***
Calories (kcal)	379 ± 44	395 ± 73	432 ± 77		**0.030***
Accelerations 1.00 - 1.99 m/s² (qty.)	71.1 ± 11.9	71.5 ± 23.2	85.0 ± 27.4		**0.034***
Decelerations –1.99 - –1.00 m/s² (qty.)	74.8 ± 8.5	76.5 ± 16.4	90.4 ± 24.3		**0.034***

c = differences between levels have analyzed with non-parametric Kruskal-Wallis test. SD = standard deviation. Qty = quantity. $p < 0.05$*, $p < 0.01$** and $p < 0.001$***.

7.5 Associations of internal and external load variables

Internal and external load variable associations are presented level by level. The associations between internal and external variables were distributed as followed: U18 a total of 16 associations, U21 a total of 59 associations and Men a total of 57 associations. The clearest area of emphasis focused on the correlations of men's high-intensity internal variables with external load variables. Internal load variables HR 70–79% and HR 80–89% are strongly correlated with external load variables. Complete matrix can be seen in appendix 4.

All the results can be seen in table 17. At U18 level, an internal variable 60-69 % of HRmax had negative connection with six different external variables. Correspondingly, the external load variable distance traveled in speedzone 18.00–21.99 km/h showed a connection with three internal variables, one of them negatively.

Table 17. Associations between internal and external load variables in U18

VARIABLES U18	HRmin mean	HRavg mean	HRmax mean	HRmin %	HRavg %	HRmax %	50–59% HRmax	60–69% HRmax	70–79% HRmax	80–89% HRmax	90–100% HRmax
Shifts	0.071	0.214	–0.524	–0.167	0.071	–0.190	–0.071	**–0.690***	0.429	0.476	–0.238
TD	0.214	0.429	–0.143	–0.071	0.381	0.071	–0.357	**–0.667***	0.405	0.524	0.071
AvgDistance	0.190	0.405	–0.071	–0.167	0.310	0.024	–0.262	**–0.643***	0.357	0.381	0.024
MaxSpeed	0.571	0.595	0.524	0.190	0.357	–0.214	–0.333	0.405	0.357	–0.476	–0.071
AvgSpeed	0.190	0.405	–0.071	–0.167	0.310	0.024	–0.262	**–0.643***	0.357	0.381	0.024
Sprints	0.515	0.599	**0.850****	0.168	**0.647***	0.299	–0.587	0.323	0.108	–0.323	0.419
TDSpeedzone1	0.214	0.262	–0.476	–0.048	–0.119	–0.476	0.000	–0.524	0.405	0.467	–0.500
TDSpeedzone2	–0.071	0.262	0.095	–0.143	0.429	0.381	–0.286	**–0.714***	0.143	0.500	0.429
TDSpeedzone3	0.095	0.476	0.262	0.095	**0.643***	0.381	–0.476	–0.548	0.333	0.452	0.524
TDSpeedzone4	0.429	**0.643***	0.476	0.286	**0.881****	0.452	**–0.810****	–0.024	0.262	0.190	0.595
TDSpeedzone5	0.476	0.548	**0.857****	0.095	0.595	0.310	–0.524	0.310	0.071	–0.381	0.405
Accelerations1	0.119	0.214	–0.310	–0.262	0.048	–0.286	0.000	–0.310	0.286	–0.048	–0.286
Accelerations2	0.000	0.143	–0.310	–0.190	–0.071	–0.333	0.095	–0.405	0.190	0.167	–0.286
Accelerations3	0.000	0.262	0.143	–0.048	0.452	0.405	–0.381	–0.548	0.024	0.524	0.452
Accelerations4	**0.663***	0.602	0.157	0.482	0.060	**–0.663***	–0.205	0.349	0.602	–0.096	–0.506
Decelerations4	0.286	0.381	**0.810****	–0.071	0.571	0.429	–0.405	0.310	–0.024	–0.571	0.500
Decelerations3	0.167	0.381	–0.048	0.024	0.143	–0.119	–0.167	**–0.667***	0.357	0.619	–0.071
Decelerations2	0.286	0.452	–0.043	–0.048	0.286	–0.071	–0.310	–0.524	0.333	0.429	–0.048
Decelerations1	0.333	0.405	–0.333	0.000	0.143	–0.357	–0.214	–0.333	0.429	0.286	–0.333

$p < 0.05$*, $p < 0.01$** and $p < 0.001$***. Statistical differences are seen as bolded values. TD = total distance. AvgDistance = average distance travelled during shifts. AvgSpeed = average speed during shifts. TDSpeedzone1 = total distance travelled in speedzone 3.00–9.99 km/h. TDSpeedzone2 = total distance travelled in speedzone 10.00–13.99 km/h. TDSpeedzone3 = total distance travelled in speedzone 14.00–17.99 km/h. TDSpeedzone4 = total distance travelled in speedzone 18.00–21.99 km/h. TDSpeedzone5 total distance travelled in speedzone >22.00 km/h). Accelerations1 = accelerations between 0.50–0.99 m/s^2. Accelerations2 = accelerations between 1.00–1.99 m/s^2. Accelerations3 = accelerations between 2.00 – 2.99 m/s^2. Accelerations4 = accelerations between 3.00–50.00 m/s^2. Decelerations4 = decelerations between –50.00 - –3.00 m/s^2. Decelerations3 = decelerations between –2.99 - –2.00 m/s^2. Decelerations2 = decelerations between –1.99 - –1.00 m/s^2. Decelerations1 = decelerations between –0.99 - –0.50 m/s^2.

Associations at U21 level can be seen in table 18. Higher number of correlations was found in U21 level when compared to U18. Internal load related variables including HR average mean, HRmax mean, and time spent in 90–100% of HRmax showed multiple correlations with external variable. Correspondingly, external load variable including maximum speed, sprints, and decelerations at speed of –2.99 - –2.00 m/s^2 all showed correlations with seven different internal variables.

Table 18. Associations between internal and external load variables in U21

VARIABLES U21	**HRmin mean**	**HRavg mean**	**HRmax mean**	**HRmin %**	**HRavg %**	**HRmax %**	**50–59% HRmax**	**60–69% HRmax**	**70–79% HRmax**	**80–89% HRmax**	**90–100% HRmax**
Shifts	0.587	**0.683***	**0.671***	0.476	0.551	0.563	–0.611	0.096	0.575	0.192	0.539
TD	0.262	0.524	0.476	0.190	0.524	0.429	–0.595	–0.381	–0.024	0.310	0.190
AvgDistance	–0.048	0.262	0.333	–0.048	0.333	0.357	–0.381	**–0.667***	–0.333	0.286	0.333
MaxSpeed	**0.643***	**0.643***	0.524	**0.690***	**0.714***	**0.762***	**–0.786***	0.190	0.619	0.524	**0.762***
AvgSpeed	–0.048	0.262	0.333	–0.048	0.333	0.357	–0.381	**–0.667***	–0.333	0.286	0.333
Sprints	**0.667***	**0.738***	**0.833****	**0.667***	0.595	**0.643***	–0.524	–0.119	0.381	0.476	**0.905****
TDSpeedzone1	**0.690***	**0.667***	0.500	**0.643***	**0.714***	**0.714***	**–0.690***	0.238	**0.690***	0.333	0.500
TDSpeedzone2	–0.119	0.238	0.310	–0.119	0.310	0.333	–0.357	–0.548	–0.429	0.333	0.310
TDSpeedzone3	0.048	0.333	0.452	0.095	0.381	0.405	–0.333	**–0.762***	–0.405	0.429	0.500
TDSpeedzone4	0.476	0.595	**0.690***	0.548	0.595	**0.643***	–0.381	–0.452	–0.024	0.595	**0.833****
TDSpeedzone5	**0.762***	**0.833****	**0.905****	**0.714***	0.619	0.619	–0.619	0.000	0.524	0.429	**0.833****
Accelerations1	**0.667***	**0.714***	0.524	**0.643***	**0.762***	**0.738***	**–0.714***	0.524	0.548	0.548	0.524
Accelerations2	0.571	**0.643***	**0.690***	0.381	0.381	0.333	–0.429	–0.048	0.548	–0.048	0.310
Accelerations3	0.238	0.429	0.571	0.310	0.452	0.524	–0.286	**–0.643***	–0.238	0,500	**0.738***
Accelerations4	0.098	0.268	0.366	0.122	0.366	0.537	–0.293	–0.415	–0.024	0.268	**0.683***
Decelerations4	**0.690***	**0.786***	**0.881****	**0.690***	0.619	0.619	–0.548	–0.190	0.310	0.524	**0.857****
Decelerations3	**0.667***	**0.690***	**0.690***	**0.667***	**0.690***	**0.738***	–0.429	–0.119	0.333	0.476	**0.762***
Decelerations2	0.381	0.595	**0.738***	0.214	0.310	0.310	–0.381	–0.071	0.262	0.071	0.452
Decelerations1	0.524	0.619	0.548	0.467	0.619	**0.667***	**–0.714***	0.143	0.548	0.333	0.619

$p < 0.05$*, $p < 0.01$** and $p < 0.001$***. Statistical differences are seen as bolded values. TD = total distance. AvgDistance = average distance travelled during shifts. AvgSpeed = average speed during shifts. TDSpeedzone1 = total distance travelled in speedzone 3.00–9.99 km/h. TDSpeedzone2 = total distance travelled in speedzone 10.00–13.99 km/h. TDSpeedzone3 = total distance travelled in speedzone 14.00–17.99 km/h. TDSpeedzone4 = total distance travelled in speedzone 18.00–21.99 km/h. TDSpeedzone5 total distance travelled in speedzone >22.00 km/h). Accelerations1 = accelerations between 0.50–0.99 m/s^2. Accelerations2 = accelerations between 1.00–1.99 m/s^2. Accelerations3 = accelerations between 2.00 – 2.99 m/s^2. Accelerations4 = accelerations between 3.00–50.00 m/s^2. Decelerations4 = decelerations between –50.00 - –3.00 m/s^2. Decelerations3 = decelerations between –2.99 - –2.00 m/s^2. Decelerations2 = decelerations between –1.99 - –1.00 m/s^2. Decelerations1 = decelerations between –0.99 - –0.50 m/s^2.

In men's level, quite similar number of associations between internal and external variables were found when compared to U21. Time spent in 80–89% HRmax had total of 14 associations with external variables. In addition, external variable decelerations at speed –50.00 - –3.00 m/s² resulted total of seven connections with internal variables. All associations at men's level can be seen in table 19.

Table 19. Associations between internal and external load variables in Men.

VARIABLES MEN	HRmin mean	HRavg mean	HRmax mean	HRmin %	HRavg %	HRmax %	50–59% HRmax	60–69% HRmax	70–79% HRmax	80–89% HRmax	90–100% HRmax
Shifts	0.262	0.395	0.214	0.048	0.500	–0.262	–0.143	–0.119	0.619	**–0.857****	–0.238
TD	0.310	0.407	0.143	0.190	0.571	–0.310	–0.238	0.143	**0.786***	**0.929****	–0.190
AvgDistance	0.238	0.383	0.143	0.119	0.595	–0.214	–0.190	–0.048	**0.667***	**0.833****	–0.071
MaxSpeed	**0.643***	**0.755***	0.500	0.619	**0.833****	0.310	**–0.667***	–0.167	0.381	0.381	0.429
AvgSpeed	0.238	0.383	0.143	0.119	0.595	–0.214	–0.190	–0.048	**0.667***	**0.833****	–0.071
Sprints	**0.833****	**0.898****	0.595	**0.762***	**0.857****	0.333	**–0.857****	0.143	0.476	0.571	0.452
TDSpeedzone1	0.024	0.132	–0.095	–0.143	0.310	–0.476	0.071	–0.190	0.571	**0.762***	–0.405
TDSpeedzone2	0.310	0.419	0.429	0.238	0.548	0.048	–0.262	0.524	**0.667***	**0.810****	0.119
TDSpeedzone3	0.595	**0.695***	0.262	0.595	**0.857****	0.048	**–0.643***	0.048	**0.690***	**0.714***	0.310
TDSpeedzone4	**0.762***	**0.850****	0.500	**0.738***	**0.905****	0.286	**–0.810****	0.095	0.548	0.595	0.476
TDSpeedzone5	**0.833****	**0.898****	0.595	**0.762***	**0.857****	0.333	**–0.857****	0.143	0.476	0.571	0.452
Accelerations1	–0.048	0.048	–0.095	–0.214	0.167	–0.405	0.143	–0.095	0.476	**0.690***	–0.357
Accelerations2	–0.167	–0.060	–0.190	–0.238	0.214	–0.452	0.214	–0.024	0.524	**0.643***	–0.333
Accelerations3	0.595	**0.731***	0.357	0.476	**0.833****	0.024	–0.571	–0.119	**0.667***	**0.810****	0.190
Accelerations4	**0.719***	**0.795****	0.599	**0.623***	**0.731***	0.419	**–0.743***	–0.084	0.192	0.311	0.467
Decelerations4	**0.690***	**0.802****	0.405	**0.643***	**0.905****	0.143	**–0.714***	0.024	**0.667***	**0.738***	0.357
Decelerations3	0.405	0.515	0.286	0.238	0.619	–0.214	–0.310	0.119	**0.762***	**0.952****	–0.143
Decelerations2	0.024	0.132	–0.095	–0.143	0.310	–0.476	0.071	–0.190	0.571	**0.762***	–0.405
Decelerations1	0.095	0.228	0.071	0.024	0.476	–0.262	–0.048	0.119	**0.690***	**0.810****	–0.119

$p < 0.05$*, $p < 0.01$** and $p < 0.001$***. Statistical differences are seen as bolded values. TD = total distance. AvgDistance = average distance travelled during shifts. AvgSpeed = average speed during shifts. TDSpeedzone1 = total distance travelled in speedzone 3.00–9.99 km/h. TDSpeedzone2 = total distance travelled in speedzone 10.00–13.99 km/h. TDSpeedzone3 = total distance travelled in speedzone 14.00–17.99 km/h. TDSpeedzone4 = total distance travelled in speedzone 18.00–21.99 km/h. TDSpeedzone5 total distance travelled in speedzone >22.00 km/h). Accelerations1 = accelerations between 0.50–0.99 m/s². Accelerations2 = accelerations between 1.00–1.99 m/s². Accelerations3 = accelerations between 2.00 – 2.99 m/s². Accelerations4 = accelerations between 3.00–50.00 m/s². Decelerations4 = decelerations between –50.00 - –3.00 m/s². Decelerations3 = decelerations between –2.99 - –2.00 m/s². Decelerations2 = decelerations between –1.99 - –1.00 m/s². Decelerations1 = decelerations between –0.99 - –0.50 m/s².

8 DISCUSSION

The main findings of this study were 1) men seem to have higher match load according to internal and external variable comparison, although only statistical significance was found in calorie consumption in match time loading, 2) in period-by-period comparison, differences between levels didn't appear in the same way as it did between levels. Seems that especially in men, the number of higher intensity actions in internal and external loading are increasing towards the end of the match, when correspondingly, at the U18 level, the result is the opposite, as the values of high-intensity actions seems to decrease as the match progresses. U21 is in the middle of these two levels, 3) floorball seems to be more high-intensity deceleration sport than high-intensity acceleration sport, 4) especially men have high amount of internal and external associations between high-intensity variables.

8.1 Total match load differences between levels

The difference in calorie consumption during the match between the levels was the only statistically significant difference. The difference between other measured variables in this study did not reach statistically significant differences between levels. Symptomatic differences could be seen in the time spent in higher end (80–89 and 90–100 %) HR zones, as well as in the distances traveled in higher end of speed zones (travelled distance in meters at >22.00 km/h). The time spent in high HR zones was a distinctive result, especially when men were compared to the U18 and U21 levels. Although statistical significance was not found between the levels, it seems that the overall load of the floorball match at the men's level is more demanding in terms of internal load variables than at the U18 or U21 levels. The percentage maximum HR during the match also supports this assumption. Similarly, at the men's level, differences in requirements during matches have already been found in futsal too, when elite and sub-elite level players have been compared (Spyrou et al. 2020).

The energy consumption becomes more pronounced as the levels progress. Moving on from the U18 level, the players' characteristics start to take shape and focus more clearly in the high intensity area. Differences in calorie consumption supports the assumption, that men have more loading during matches than U18 or U21 level players. In the comparison between the levels, the symptomatic significances give direction to how floorball as a sport differs between the levels as the players get older.

8.2 Match load differences between periods in different levels of play

In the comparison between the levels and the periods, there were hardly any differences. The only clear difference was found in the distance traveled in the different speed ranges in the third period, which gives an indication of the intensity difference between the levels. However, it should be noted that in the comparison of three different levels, a clearer distinctiveness would require considerable differences from both levels. Thus, for example, when one level differs from another, the third level can balance the comparison between all of them. Also, it has to be mentioned, that matches are never the same, so loads and changes can greatly effect on results of match load analysis. For example, tactics, the skill level of the player or players, or the rules can affect the load during the match. In floorball, it is possible to get penalties, which in themselves shape the balance of the teams in terms of the number of players on the court.

Based on the results, the intensity at different levels would seem to be similar. In this study, intensity has been measured by changes in speed. As the speed changes, the results are stored in the system with different criteria, which are divided into distance traveled in different speed zones, and number of repetitions in different acceleration and deceleration zones. In the measurements, there were hardly any statistically significant differences between the levels in the areas of acceleration or deceleration. The only statistical difference was found in the measurements of the first period, where the amount of the acceleration range 0.50 – 0.99 m/s^2 was different at the U21 level compared to the other two.

Although statistically significant differences were not found in period-by-period comparisons between levels, the differences in periodic comparisons within levels were found. In terms of match-time intensity variation, differences between levels can be seen as changes in high-intensity performance between periods. Comparing the difference between U18 and men, at the U18 level the demands of high intensity are in decreasing proportion towards the end of the match. Correspondingly, at the men's level, the trend is on the rise, as the number of high-intensity performances during the match is increasing towards the end of the match. Which is interesting, because when compared for example to soccer, high-intensity playing decreases towards the end of the match (Mohr et al. 2003; Bangsbo et al. 2006). The U21 level results were somewhere between U18 and men's levels.

However, in the comparison of the variables, an interesting difference was found between the values of the highest accelerations and decelerations (3.00 - 50.00 m/s^2 and –50.00 - –3.00 m/s^2), as the number of decelerations at all levels in the entire match was significantly larger than the accelerations ($p = 0.005$ at all levels) According to Harper et al. (2019) listing, floorball ranks in the category of intensity viewed through accelerations and decelerations in the same classification as for example, Australian football, soccer, hockey and rugby. This indicates that floorball may be more of a high-intensity deceleration sport than high-intensity acceleration sport. It should be noted, however, that sport specific variation may also appear. For example, in ice hockey, there have been recorded different kind of results depending on playing positions. (Harper et al. 2019.) In floorball, the matter cannot be clarified with this study, because due to the number of subjects, conclusions specific to the game venue, or even indicative results, cannot be interpreted.

During a match, a floorball player performs more high-intensity decelerations than accelerations. However, information can be viewed from different perspectives. It is possible that for the measurements performed on the subjects, the subjects' force output in terms of speed was not at a level that the equipment would have registered this. On the other hand, the matter can also be seen in the way that the test subjects reached high speeds during the matches, but not in the amount of time for which the measuring equipment was calibrated. (Fox et al. 2019.) However, it can be seen from the results that the ratio of accelerations and decelerations of all levels was the same. The conclusion can be drawn from this that in a floorball match, decelerations may be more important than accelerations. In terms of the risk of injury, the loads on the knees are a matter to consider, because high-intensity deceleration followed by a change of direction places greater loads on the knees than, for example, a drop jump (Kristianslund & Krosshaug 2013).

In terms of external load, previous studies have been carried out especially from the injury risk point of view. Leppänen et al. (2020) found that poor pelvic control is associated with ACL injuries in young athletes, when measured in a standing knee lift test. Based on the results of this study, special attention should be paid to high-intensity decelerations and subsequent direction changes. Since the maximum speeds do not differ much between the levels, especially the players at the U18 and U21 levels should pay attention to the hip control in training. However, the need to control the pelvic area should not disappear at the adult level, because the number of repetitions measured through higher intensities increase when moving to the adult level. At the same time, overall load emphasizes more towards the end of the game in Men than U18 or U21. Leppänen et al. (2021) studied the change of direction technique from a biomechanical perspective but did not find a statistically significant relationship between injuries and change of direction technique in young players. However, differences were found between injured and non-injured in valgus knee angles, but as mentioned, no statistical significance was found.

In floorball matches, it has been found that most injuries occur in the knee and ankle area during matches and training. Of these injuries, 27 % were in the knee area, and 22 % in the ankle area. (Pasanen et al. 2008a.) In high-intensity accelerations and decelerations, the contribution of the neuromuscular system to the functioning of muscle work methods is emphasized. Since, based on the results, it can be concluded that eccentric high-intensity actions are more prominent in floorball matches than concentric actions, and so attention should be paid to the performance of the neuromuscular system. In addition, Pasanen et al. (2008b) found that with an initial warm-up focusing on the functioning of the neuromuscular system, the risk of injury in floorball matches and practice can be reduced, especially in non-contact situations.

As the results suggest that the need of high-intensity performance increases with age, and at the men's level within a match, the maintenance of high-intensity performance should therefore be considered as a clear part of training. Combined with the high deceleration requirement, the need of maximal force in the shortest amount of time would guide thinking especially in the direction of plyometric training. Based on previous studies, for all levels, plyometric training can both prevent injuries (Pasanen et al. 2008b; Yanci et al. 2016) and develop the performance of both young and older players (Beato et al. 2018; Markovic & Mikulic 2010). Although it is important, that the training includes also other types of eccentric training methods rather than just one. There is an indication that eccentric flywheel training (isoinertial) improves adolescents more than traditional plyometric training (Fiorilli et al. 2020), indicating that several methods of eccentric training can lead to an improvement (McNeill et al. 2019).

8.3 Associations in internal and external variables

Associations between internal and external load variables were found in this study at all levels. However, there were noticeable differences in the comparison between the levels, as the number of associated load variables at the U18 level was significantly lower compared to the U21 and men's levels. At the U18 level, the total number of correlations was 16 associations, while correspondingly at the U21 level, 59 and at the men's level 57 associations were found between variables. Based on the results, it would seem that at the men's level the associations are particularly focused on high-intensity heart rate areas, as 23 correlations between external load variables appeared in the 70–89%HRmax areas.

According to previous studies, total distance (TD) from external load variables would seem to have the clearest association with internal load variables. In particular, the subjects' session rating of perceived exertion (sRPE) is strongly associated with the distance traveled. (McLaren et al. 2017.) An interesting result in this study is that the U18 and U21 levels did not show associations with TD in terms of internal load (except for U18 60–69% HRmax r = -0.667), but in men's level, a association occurred with TD and 70 –79 % HRmax (r = 0.786) and also with TD and 80–89 % HRmax (r = 0.929). In the study conducted by Beato and Drust (2020), similar indications were seen when investigating the effect of different accelerations on internal load variables in soccer players.

Based on the comparison between levels, indications of the associations show clearer emphasis in physiological needs when moving to the men's level. With the change of age and series level, the associations between load variables give more indications that accumulated load of an adult floorball player is based on high-intensity performances with a short duration. However, it is possible that the load variables are also affected by the development of an individual's motor skill factors in running with age. For example, Wang et al. (2021) investigated the biomechanics of different running speeds between athletes and non-athletes, and the largest differences were found in differences at the highest running speed when comparing the differences between the groups in the hip-knee and knee-ankle axes. In particular, the variability of ankle mobility during sprints emerged as a distinguishing factor between the groups based on the results, which could be an explanatory factor for the movement of the external load in this study. (Wang et al. 2021.)

Previous studies also show that children and adolescents recover faster from maximal exercise, due to lower lactate values during exercise (Zanconato et al. 1993). Based on the results of this study, it can also be thought that, in addition to skill and tactical factors, physiological development can be an explanatory factor for the differences in associations between internal and external load variables between levels. It is also stated that the faster recovery of children and young people may also be due to the fact that, compared to men, the peak power output is lower, thus causing smaller amounts of lactate during maximal performance (Falk & Dotan 2006). However, lactate level measurements were not included to this study and would require therefore further investigations between levels.

8.4 Strengths and limitations

A few separate factors can be considered the strength of this study. The measurements were carried out on elite level athletes, in official floorball matches. The matches accepted for the study were limited in such a way that the difference between the teams was no more than three goals at the beginning of the third period. In addition, the emphasis of the analyzed matches has been focused more towards the end of the regular season than the beginning, in which case the significance of the matches in terms of the final result has been emphasized. It has also been possible to set the number of subjects to be the same at all three levels. It is also not known that a similar kind of study has been carried out before for floorball, where a comparison could have been made between the three highest league levels.

The limitation of the study can be considered the number of subjects. The number of eight subjects is not sufficient to make larger outlines or demarcations aimed at the levels. For example, regarding statistical significances, nonparametric analysis methods had to be used to clarify the differences between the levels. Nonparametric analysis methods are not the most reliable for determining statistical significance. In addition, the method used for measurements is not valid for indoor measurements, as GPS-based measurement has not shown completely reliable results in indoor measurements (Fox et al. 2019), and most of the results are leaning on inertial measurements system. Therefore, it must be outlined that the conclusions from this study need to be carefully examined.

8.5 Conclusions

The physiological requirements of the highest men's series level and the differences compared to the highest U18 and U21 levels are manifested especially in high-intensity performance. In addition, at the men's level, there seems to be the most variation between periods, which shows a greater demand for the body to adapt to the game. At the U18 level, loading would seem to have a downward trend, which is manifested by an increase in lower intensity values, while at the men's level, the direction would seem to be the opposite. Explanatory factors can be the skill level of individual players, physiological development, or lack of development of physiological characteristics in relation to age, in which case high-intensity performance cannot yet be maintained during the match. In addition, it is proved that younger players may not reach the maximal values of performance in the same amount of time as adults. It is also possible that the tactical side of the game affects the physical loading, as the measurements were taken in official floorball matches where the result is important for the series.

For all levels, the difference between high-intensity decelerations and accelerations is essential, because floorball as a sport seems to require more high-intensity eccentric muscle work from the neuromuscular system than high-intensity concentric muscle work. The ratio of the stretch-shortening cycle of the muscle is probably the same, but the importance of eccentric muscle work is emphasized in high-intensity decelerations, which are performed more than accelerations during the match player performs during the match. This applies to all levels.

Alongside the previous research data, this study confirms the previously stated finding in terms of the importance of the neuromuscular system.

8.6 Practical applications

With age and levels going forward, the match-specific load of a floorball player increases, especially in high-intensity variables. At the U18 level, the values of high intensity are decreasing, while, correspondingly, at the men's level, the intensity increases towards the end of the match. Probable explanatory factors for this are motor skill development in relation to movement skills, physiological development, skill development and the sum of the above. Therefore, coaches with younger players should provide an environment that stimulate all these specific aspects. Movement skill could be adapted with the skill of high-intensity play with or without a ball, although this should be periodized to a match time performance and the state of individual capabilities. Combined with sport-specific skills (such as passing, receiving a pass, shooting, change of direction with or without ball), it could provide more beneficial physiological abilities when moving towards adults' level.

In terms of calorie consumption, at the men's level, the increasing loads of the match maintain or increase energy consumption, producing a significant difference in terms of total energy consumption compared to the other two levels. Therefore, it could be useful to pay attention to nutritional side as well, approaching it from sport-specific point of view.

For all three levels, the significant factor is the proportion of high-intensity deceleration in movement during the match. The importance of strength should not be underestimated in the sport, because due to the high-intensity requirement, the muscle's ability to produce especially high-intensity eccentric force during changes of directions and decelerations is an essential factor in floorball.

Results from this study supports previous conclusions that neuromuscular training could prevent ankle and knee injuries in floorball.

REFERENCES

Abdelkrim, B. N., Castagna, N., El Fazaa, C. & El Ati, J. 2010a. The Effect of Players' Standard and Tactical Strategy on Game Demands in Men's Basketball. Journal of Strength and Conditioning Research 24(10), 2652–2662. doi:10.1519/jsc.0b013e3181e2e0a3.

Abdelkrim. B. N., Chaouchi, A., Chamari, K., Chtara, M. & Castagna, C. 2010b. Positional Role and Competitive-Level Differences in Elite-Level Men's Basketball Players. Journal of Strength and Conditioning Research 24(5), 1346–1355. doi:10.1519/jsc.0b013e3181cf7510.

Akyildiz, Z., Yildiz, M. & Clemente, F. M. 2020. The Reliability and Accuracy of Polar Team Pro GPS Units. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology 175433712097666, doi:10.1177/1754337120976660.

Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M. A. & Al-Khalifa, H. S. 2016. Ultra-Wideband Indoor Positioning Technologies: Analysis and Recent Advances. Sensors 16(5):707 doi:10.3390/s16050707.

Álvarez, J. C. B., D'ottavio, S., Vera, J. G. & Castagna, C. 2009. Aerobic Fitness in Futsal Players of Different Competitive Level. Journal of Strength and Conditioning Research 23(7), 2163–2166. doi:10.1519/jsc.0b013e3181b7f8ad.

Ament, W. & Verkerke, G. J. 2009. Exercise and Fatigue. Sports Medicine 39(5), 389–422. doi:10.2165/00007256-200939050-00005.

Amirthalingam, T., Mavros, Y., Wilson, G. C., Clarke, J. L., Mitchell, L. & Hackett, D. A. 2016. Effects of a Modified German Volume Training Program on Muscular Hypertrophy and Strength. Journal of Strength and Conditioning Research 31(11), 3109–3119. doi:10.1519/jsc.0000000000001747.

Attene, G., Laffaye, G., Chaouachi, A., Pizzolato, F., Migliaccio, G. M. & Padulo, J. 2015. Repeated Sprint Ability in Young Basketball Players: One vs. Two Changes of Direction. Journal of Sports Sciences 33(15), 1553–1563. doi:10.1080/02640414.2014.996182.

Aughey, R. J. 2011. Applications of GPS Technologies to Field Sports. International Journal of Sports Physiology and Performance 6(3), 295–310. doi:10.1123/ijspp.6.3.295.

Baker, L. B., Rollo, I., Stein, K. W., Jeukendrup, A. E. 2015. Acute Effects of Carbohydrate Supplementation on Intermittent Sports Performance. Nutrients 7(7), 5733–5763. doi:10.3390/nu7075249.

Bangsbo, J. & Lindquist, F. 1992. Comparison of Various Exercise Tests with Endurance Performance during Soccer in Professional Players. International Journal of Sports Medicine 13(2), 125–132. doi:10.1055/s-2007-1021243.

Bangsbo, J., Mohr, M. & Krustrup P. 2006. Physical and metabolic demands of training and match-play in the elite football player. Journal of Sports Sciences 24(7), 665–674. doi:10.1080/02640410500482529.

Bastida-Castillo, A., Gómez Carmona, C. D., De La Cruz Sánchez, Ernesto & Pino Ortega, J. 2018. Accuracy, intra- and inter-unit reliability, and comparison between GPS and UWB-based position-tracking systems used for time–motion analyses in soccer Informa UK Limited 18. doi:10.1080/17461391.2018.1427796.

Bastida-Castillo, A., Gómez-Carmona, C., De la Cruz-Sánchez, E., Reche-Royo, X., Ibáñez, S. & Pino Ortega, J. 2019. Accuracy and inter-unit reliability of ultra-wide-band tracking system in indoor exercise. Applied Sciences 9 (5), 939. doi:10.3390/app9050939.

Beato, M., Bianchi, M., Coratella, G., Merlini, M. & Drust, B. 2018. Effects of Plyometric and Directional Training on Speed and Jump Performance in Elite Youth Soccer Players. Journal of Strength and Conditioning Research, 1. doi:10.1519/jsc0000000000002371.

Beato, M. & Drust, B. 2020. Acceleration intensity is an important contributor to the external and internal training load demands of repeated sprint exercises in soccer players. Research in Sports Medicine, 1–10. doi:10.1080/15438627.2020.1743.

Beneke, R. & von Duvillard, S. P. 1996. Determination of Maximal Lactate Steady State Response in Selected Sports Events. Medicine and Science in Sports and Exercise 28(2), 241–246. doi:10.1097/00005768-199602000-00013.

Bosco, C., Tihanyi, J. & Viru A. 1996. Relationship Between Field Fitness Test and Basal Serum Testosterone and Cortisol Levels in Soccer Players. Clinical Physiology 16(3), 317–322. doi.10.1111/j.1475-097x.1996.tb00577.x.

Bouchard, C. & Rankinen, T. 2001. Individual Differences in Response to Regular Physical Activity. Medicine and Science in Sports and Exercise 33(Supplement), 446–451. doi:10.1097/00005768-200106001-00013.

Bowen, L., Gross, A. S., Gimpel, M. & Li, F-X. 2017. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. British Journal of Sports Medicine 51(5), 452–459. doi:10.1136/bjsports-2015-095820.

Brancaccio, P., Maffulli, N. & Limongelli, F. M. 2007. Creatine kinase monitoring in sport medicine. British Medical Bulletin 81–82(1), 209–230. doi:10.1093/bmb/1dm014.

Buchheit, M. & Simpson, B. M. 2017. Player-Tracking Technology: Half-Full or Half-Empty Glass? International Journal of Sports Physiology and Performance 12(Suppl 2), S2–35–S2–41. doi:10.1123/ijspp.2016-0499.

Bueno, M. J. de O., Caetano, F. G., Yonezawa, M. K., Grella, A. S., Cunha, S. A. & Moura, F. A. 2018. How do futsal players of different categories play during official matches? A tactical approach to players' organization on the court from positional data. PLOS ONE 13(6), e0199619. doi:10.1371/journal.pone.0199619.

Bueno, M. J. de O., Caetano, F. G., Pereira, T. J. C., De Souza, N. M., Moreira, G. D., Nakamura, F. Y., Cunha, S. A. & Moura, F. A. 2014. Analysis of the distance covered by Brazilian professional futsal players during official matches. Sports Biomechanics 13(3), 230–240. doi:10.1080/14763141.2014.958872.

Caetano, F. G., de Oliveira, M. J., Marche, A. L., Nakamura, F. Y., Cunha, S. A. & Moura, F. A. 2015. Characterization of the sprint and repeated-sprint sequences performed by professional futsal players, according to playing position, during official matches. Journal of Applied Biomechanics 31(6), 423–429. doi:10.1123/jab.2014-0159.

Cairns, S. P. 2006. Lactic Acid and Exercise Performance. Sports Medicine 36(4), 279–291. doi:10.2165/00007256-200636040-00001.

Carranza-García, L. E., George, K., Serrano-Ostáriz, E., Casado-Arroyo. R., Caballero-Navarro, A., L. & Legaz-Arrese, A. 2011. Cardiac Biomarker Response to Intermittent Exercise Bouts. International Journal of Sports Medicine 32(05), 327–331. doi:10.1055/s-0030-1263138.

Casado, A., González-Mohíno, F., González-Ravé, J. M. & Foster, C. 2022. Training Periodization, Methods, Intensity Distribution, and Volume in Highly Trained and Elite Distance Runners: A Systematic Review. International Journal of Sports Physiological Performance 17(6), 820–833. doi:10.1123(ijspp.2021-0435.

Castagna, C., Abt, G., Manzi, V., Annino, G., Padua, E. & D'Ottavio, S. 2008. Effect of Recovery Mode on Repeated Sprint Ability in Young Basketball Players. Journal of

Strength and Conditioning Research 22(3), 923–929. doi:10.1519/jsc.0b013e31816a4281.

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. doi:10.1519/jsc.0b013e3182030e43.

Coffey, V. G. & Hawley, J. A. 2007. The Molecular Bases of Training Adaptation. Sports Medicine 37(9), 737–763. doi:10.2165/00007256-200737090-00001.

Conte, D. 2020. Validity of local positioning systems to measure external load in sport settings: A brief review. Human Movement 21 (4), 30-36. doi:10.5114/hm.2020.94200.

Colby, M. J., Dawson, B., Heasman, J., Rogalski, B. & Gabbet, T. J. 2014. Accelerometer and GPS-Derived Running Loads and Injury Risk in Elite Australian Footballers. Journal of Strength and Conditioning Research 28(8), 2244–2252. doi:10.1519/jsc.0000000000000362.

Cummins, C., Orr, R., O'Connor, H. & West, C. 2013. Global Positioning Systems (GPS) and Microtechnology Sensors in Team Sports: A Systematic Review. Sports Medicine 43(10), 1025–1042. doi:10.1007/s40279-013-0069-2.

Cummins, C., Welch, M., Inkster, B., Cupples, B., Weaving, D., Jones, B., King, D. & Murphy, A. 2018. Modelling the relationship between volume, intensity and injury-risk in professional rugby league players. Journal of Science and Medicine in Sport, (). doi:10.1016/j.jsams.2018.11.028.

Cunniffe, B., Proctor, W., Baker, J. S. & Davies, B. 2009. An Evaluation of the Physiological Demands of Elite Rugby Union Using Global Positioning System Tracking Software, Journal of Strength & Conditioning Research 23(4), 1195–1203. doi:101519/JSC.0b013e3181a3928b.

DeMartini, J. K., Martschinske, J. L., Casa, D. J., Lopez, R. M., Ganio, M. S., Walz, S. M. & Coris, E. E. 2011. Physical Demands of National Collegiate Athletic Association Divison I Football Players During Preseason Training in the Heat. Journal of Strength and Conditioning Research 25(11), 2935–2943. doi:10.1519/jsc.0b013e318231a643.

Dello Iacono, A., Ardigò, L. P., Meckel, Y. & Padulo, J. 2016. Effect of Small-Sided Games and Repeated Shuffle Sprint Training on Physical Performance in Elite Handball

Players. Journal of Strength and Conditioning Research 30(3), 830–840. doi:10.1519/jsc.0000000000001139.

Dello Iacono, A. Eliakim, A. & Meckel, Y. 2015. Improving Fitness of Elite Handball Players: Small-Sided Games vs. High-Intensity Intermitted Training. Journal of Strength and Conditioning Research 29(3), 835–843. doi:10.1519/jsc.0000000000000686.

Dogramaci, S. N., Watsford, M. L. & Murphy, A. J. 2011. Time-Motion Analysis of International and National Level Futsal. Journal of Strength and Conditioning Research 25(3), 646–651. doi:10.1519/jsc.0b013e3181c6a02e.

Drew, M. K. & Finch, C. F. 2016. The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic Review. Sports Medicine 46(6), 861–883. doi:10.1007/s40279-015-0459-8.

Dwyer, D. B. & Gabbet, T. J. 2012. Global Positioning System Data Analysis: Velocity Ranges and a New Definition of Sprinting for Field Sport Athletes. Journal of Strength and Conditioning Research, 26(3), 818–824. doi:10.1519/jsc.0b013e3182276555.

Falk, B. & Dotan, R. 2006. Child-Adult Differences in the Recovery from High-Intensity Exercise. Exercise and Sport Sciences Reviews 34(3), 107–112. doi:10.1249/00003677-200607000-00004.

Fiorilli, G., Mariano, I., Iuliano, E., Giombini, A., Ciccarelli, A., Buonsenso, A., Calcagno, G. & di Cagno, A. 2020. Isoinertial Eccentric-Overload Training in Young Soccer Players: Effects on Strength, Sprint, Change of Direction, Agility and Soccer Shooting Precision. Journal of Sports Science Medicine 19(1), 213–223. PMID:32132845.

Ferland, P-M., Marcotte-L'Heureux, V., Roy, P., Carey, V., Charron, J., Lagrange, S., Leone, M. & Comtois, A. S. 2021. Maximal Oxygen Consumption Requirements in Professional North American Ice Hockey. Journal of Strength and Conditioning Research 35(6), 1586–1592. doi:10.1519/jsc.0000000000003966.

Font, R., Karcher, C., Reche, X., Carmona, G., Tremps, V. & Irurtia, A. 2021. Monitoring external load in elite male handball players depending on playing positions. Biology of Sport 38(3), 475–481. doi:10.5114/biolsport.2021.101123.

Fox, J. L., Stanton, R., Sargent, C., Wintour, S.-A. & Scanlan, A. T. 2018. The Association Between Training Load and Performance in Team Sports: A Systematic Review. Sports Medicine 48(12), 2743–2774. doi:10.1007/s40279-018-0982-5.

Fox, J. L., O'Grady, C. J., Scanlan, A. T., Sargent, C. & Stanton, R. 2019. Validity of the Polar Team Pro Sensor for measuring speed and distance indoors. Journal of Science and Medicine in Sport 22(11), 1260–1265. doi:10.1016/j.jsams.2019.06.012.

Gabbett, T., J. 2016. The Training-injury Prevention Paradox: Should Athletes be Training Smarterandharded? British Journal of Sports Medicine 50(5), 273–280. doi:10.1136/bjsports-2015-095788.

Gastin, P. B. 2001. Energy System Interaction and Relative Contribution During Maximal Exercise. Sports Medicine 31(10), 725–741. doi:10.2165/00007256-200131100-00003.

Gladden, L. B. 2004. Lactate metabolism: a new paradigm for the third millennium. The Journal of Physiology 558(1), 5–30. doi:10.1113/jphysiol.2003.058701.

Harper, D. J., Carling, C. & Kiely, J. 2019. High-Intensity Acceleration and Deceleration Demands in Elite Team Sports Competitive Match Play: A Systematic Review and Meta-Analysis of Observational Studies. Sports Medicine 49(12), 1923–1947. doi:10.1007/s40279-019-01170-1.

Hokka, J. 2001. Fyysisen harjoittelun osa-alueet ja niiden harjoittamisen problematiikka salibandyssa. University of Jyväskylä. Pro Gradu -thesis.

Huggins, R. A., Giersch, G. E. W., Belval, L. N., Benjamin, C. L., Curtis, R. M., Sekiguchi, Y., Peltonen, J. & Casa, D. J. 2020. The Validity and Reliability of Global Positioning System Units for Measuring Distance and Velocity Durin Linear and Team Sport Simulated Movements. Journal of Strength and Conditioning Research 34(11), 3070–3077. doi:10.1519/jsc.0000000000003787.

Impellizzeri, F. M., Rampanini, E. & Marcora, S. M. 2005. Physiological Assessment in Soccer. Journal of Sports Sciences 23(6), 583–592. doi:10.1080/02640410400021278.

International Floorball Federation. 2020. Floorball in a Nutshell. Referenced: 21.2.2022. Available at: https://floorball.sport/this-is-floorball/floorball-in-a-nutshell/.

Irnich, W. 2002. Electronic Security Systems and Active Implantable Medical Devices. Journal of Pacing and Clinical Electrophysiology 25(8), 1235–1258. doi:10.1046/j.1460-9592.2002.01235.x.

Jimenez-Reyes, P., Pareja-Blanco, V., Cuadrado-Peñafiel, V., Morcillo, J., Párraga, J. & Gonzáles-Badillo, J. 2016. Mechanical, Metabolic and Perceptual Response during Sprint Training. International Journal of Sports Medicine 37(10), 807–812. doi:10.1055/s-0042-107251.

Kainulainen, J. 2015. Salibandypelaajan suorituskykyprofiili ja muutokset sarjakauden aikana. University of Jyväskylä. Pro Gradu -thesis.

Kelly, D. T., Tobin, C., Egan, B., Carren, A. M., O'Connor, P. L., McCaffrey, N. & Moyna, N. M. 2018. Comparison of sprint interval and endurance training in team sport athletes. Journal of Strength and Conditioning Research, 1. doi:10.1519/jsc.0000000000002374.

Kirsilä, J. & Wenning, J. 2019. Salibandyn Lajianalyysi ja Salibandyn Laukauksen Biomekaaninen Analyysi sekä Valmennuksen Ohjelmointi. University of Jyväskylä. Seminar work.

Krieger, J. W. 2010. Single vs. Multiple Sets of Resistance Exercise for Muscle Hypertrophy: A Meta-Analysis. Journal of Strength and Conditioning Research 24(4), 1150–1159. doi:10.1519/jsc.0b013e3181d4d436.

Kristianslund, E. & Krosshaug, T. 2013. Comparison of drop jumps and sport-specific sidestep cutting: implications for anterior cruciate ligament injury risk screening. American Journal of Sports Medicine 41(3), 684–688. doi:10.1177/0363546512472043.

Kumar, S. & Moore, K. B. 2002. The Evolution of Global Positioning System (GPS) Technology. Journal of Science Education and Technology 11(1), 59–80. doi:10.1023/a:1013999415003.

Kupperman, N. & Hertel, J. 2020. Global Positioning System-Derived Workload Metrics and Injury Risk in Team-Based Field Sports: A Systematic Review. Journal of Athletic Training 55(9), 931–943. doi:10.4085/1062-6050-473-19.

Larsen, M. N., Madsen, M., Nielsen, C. M., Manniche, V., Hansen, L., Bangsbo, J., Krustrup, P. & Hansen, P. R. 2020. Cardiovascular adaptations after 10 months of daily 12-min bouts of intense school-based physical training for 8-10-year-old children. Progress in Cardiovascular Diseases 63(3), 813–817. doi:10.1016/j.pcad.2020.05..011.

Larsson, P. 2003. Global positioning system and sport-specific testing. Sports Medicine 33(15), 1093–1101. doi:10.2165/00007256-200333150-00002.

Leger, L., Seliger, V. & Brassard, L. 1979. Comparisons among VO2max values for hockey players and runners. Canadian Journal of Applied Sport Sciences, 4: 18–21.

Leppänen, M. Rossi, M. T., Parkkari, J., Heinonen, A., Äyrämö, S., Krosshaug, T., Vasankari, T., Kannus, P. & Pasanen, K. 2020. Altered hip control during a standing knee-lift test is associated with increased risk of knee injuries. Scandinavian Journal of Medicine & Science in Sports 30(5), 922–931. doi:10.1111/sms.13626.

Leppänen, M., Parkkari, J., Vasankari, T., Äyrämö, S., Kulmala, JP., Krosshauh, T., Kannus, P. & Pasanen, K. 2021. Change of Direction Biomechanics in a 180-Degree Pivot Turn and the Risk for Noncontact Knee Injuries in Youth Basketball and Floorball Players. American Journal of Sports Medicine 49(10), 2651–2658. doi:10.1177/03635465211026944.

Lignell, E., Fransson, D., Krustrup, P. & Mohr, M. 2018. Analysis of High-Intensity Skating in Top-Class Ice Hockey Match-Play in Relation to Training Status and Muscle Damage. Journal of Strength and Conditioning Research 32(5), 1303–1310. doi:10.1519/jsc.0000000000001999.

MacInnis, M. J. & Gibala M. J. 2016. Physiological Adaptations to Interval Training and The Role of Exercise Intensity. The Journal of Physiology 595(9), 2915–2930. doi:10.1113/jp273196.

Malone, J. J., Lovell, R., Varley, M. C. & Coutts, A. J. 2017. Unpacking the Black Box: Applications and Considerations for Using GPS Devices in Sport. International Journal of Sports Physiology and Performance 12(Suppl 2), S2-18–S2-26. doi:10.1123/ijspp.2016-0236.

Markovic, G. & Mikulic, P. 2010. Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training. Sports Medicine 40(10), 859–895. doi:10.2165/11318370-000000000-00000.

McLaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R. & Weston, M. 2017. The Relationship Between Internal and External Measures of Training Load and Intensity in Team Sports: A Meta-Analysis. Sports Medicine 48(3), 641–658. doi:10.1007/s40279-017-0830-z.

McNeill, C., Beaven, C. M., McMaster, D. T. & Gill, N. 2019. Eccentric Training Interventions and Team Sport Athletes. Journal of Fuctional Morphology and Kinesiology 4(4), 67. doi:10.3390/jfmk4040067.

Michalsik, L. B., Madsen, K. & Aagaard, P. 2015. Physiological capacity and physical testing in male elite team handball. Journal of Sports Medicine and Physical Fitness 55(5), 415–429.

Milanez, V. F., Pedro, R. E., Moreira, A., Boullosa, D. A., Salle-Neto, F. & Nakamura, F. Y. 2011. The Role of Aerobic Fitness on Session Rating of Perceived Exertion in Futsal

Players. International Journal of Sports Physiology and Performance 6(3), 358–366. doi:10.1123/ijspp.6.3.358.

Mohr, M., Krustrup, P., Nielsen, J. J., Nybo, L., Rasmussen, M. K., Juel, C. & Bangsbo, J. 2007. Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology 292(4), 1594–1602. doi:10.1152/ajpregu.00251.2006.

Mohr, M., Krustrup, P. & Bangsbo, J. 2003. Match performance of high-standard soccer players with special reference to development of fatigue. Journal of Sports Sciences 21, 439–449. doi:10.1080/0264041031000071182.

Mu, H. & Yao, J. 2010. Photonic generation of UWB pulses with pulse position modulation. Electronics Letters 46(1), 99–100. doi:10.1049/el.2010.3154.

Murray, N. B., Gabbett, T. J., Townshend, A. D., Hulin, B. T. & McLellan, C. P. 2017. Individual and combined effects of acute and chronic running loads on injury risk in elite Australian footballers. Scandinavian Journal of Medicine & Science in Sports 27(9), 990–998. doi:10.1111/sms.12719.

Narazaki, K., Berg, K., Stergiou, N. & Chen, B. 2009. Physiological Demands of Competitive Basketball. Scandinavian Journal of Medicine & Science in Sports 19(3), 425–432. doi:10.1111/j.1600-0838.2008.00789.x.

Nikolaidis, P. T. & Ingebrigtsen, J. 2013. Physical and Physiological Characteristics of Elite Male Handball Players from Teams with a Different Ranking. Journal of Human Kinetics 38, 115–124. doi:10.2478/hukin-2013-0051.

Pasanen, K., Parkkari, J., Kannus, P., Rossi, L., Palvanen, M., Natri, A. & Järvinen, M. 2008a. Injury risk in female floorball: a prospective one-season follow-up. Scandinavian Journal of Medicine & Science in Sports 18(1), 49–54. doi:10.1111/j.1600-0838.2007.00640.x.

Pasanen, K., Parkkari, J., Pasanen, M., Hiilloskorpi, H., Mäkinen, T., Järvinen, M. & Kannus, P. 2008b. Neuromuscular training and the risk of leg injury in female floorball players: cluster randomised controlled study. British Journal of Sports Medicine 42(10), 502–505. doi:10.1136/bmj.a295.

Pedersen, M. T., Vorup, J. & Bangsbo, J. 2018. Effect of a 26-month floorball training on male elderly's cardiovascular fitness, glucose control, body composition, and functional capacity. Journal of Sport and Health Science 7(2), 149–158. doi:10.1016/j.jshs.2017.12.002.

Petway, A. J., Freitas, T. T., Calleja-González, J., Medina Leal, D. & Alcaraz, P. E. 2020. Training load and match-play demands in basketball based on competition level: A systematic review. PLOS ONE 15(3), e0229212. doi:10.1371/journal.pone.0229212.

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. 2014. Physiological Demands of Elite Team Handball With Special Reference to Playing Position. Journal of Strength and Conditioning Research 28(2), 430–442. doi:10.1519/jsc.0b013e3182a953b1.

Rampanini, E., Bishop, D., Marcora, S., Ferrari Bravo, D., Sassi, R. & Impellizzeri, F. 2007. Validity of Simple Field Tests as Indicators of Match-Related Physical Performance in Top-Level Professional Soccer Players. International Journal of Sports Medicine 28(3), 228–235. doi:10.1055/s-2006-924340.

Rhea, M. R., Alvar, B. A., Burkett, L. N. & Ball, S. D. 2003. A Meta-analysis to Determine the Dose Response for Strength Development. Medicine & Science in Sports & Exercise 35(3), 456–464. doi:10.1249/01.MSS.0000053727.63505.D4.

Rico-González, M., Los Arcos, A., Rojas-Valverde, D., Clemente, F. M. & Pino-Ortega, J. 2020. A Survey to Assess the Quality of the Data Obtained by Radio-Frequency Technologies and Microelectromechanical Systems to Measure External Workload and Collective Behavior Variables in Team Sports. Sensors 20(8), 2271. doi:10.3390/s20082271.

Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Love, T. D., Bracken, R. M. & Kilduff, L. P. 2014. Changes in Acceleration and Deceleration Capacity Throughout Professional Soccer Match-Play. Journal of Strength and Conditioning Research, 30(10), 2839–2844. doi:10.1519/jsc.0000000000000805.

Scanlan, A., Dascombe, B. & Reaburn, P. 2011. A comparison of the activity demands of elite and sub-elite Australian men’s basketball competition. Journal of Sports Sciences 29(11), 1153–1160. doi:10.1080/02640414.2011.582509.

Seiler, S. 2010. What is Best Practise for Training Intensity and Duration Distribution in Endurance Athletes? International Journal of Sports Physiology and Performance 5(3), 276–291. doi:10.1123/ijspp.5.3.276.

Seiler, K. S. & Kjerland, G. O. 2006. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution? Scandinavian Journal of Medicine and Science in Sports 16(1), 49–56. doi:10.1111/j.1600-0838.2004.00418.x.

Serpiello, F. R., Hopkins, W. G., Barnes, S., Tavrou, J., Duthie, G. M., Aughey, R. J. & Ball, K. 2017. Validity of an ultra-wideband local positioning system to measure locomotion in indoor sports. Journal of Sports Sciences 36(15), 1727–1733. doi:10.1080/02640414.2017.1411867.

Sharma, S. 2004. Cardiac Troponins. Journal of Clinical Pathology 57(10), 1025–1026. doi:10.1136/jcp.2003.015420.

Sobolewski, E. J. 2020. The Relationship between Internal and External Load Measures for Division I College Football Practise. Sports 8(12), 165. doi:10.3390/sports8120165.

Spina, R. J., Chi, M. M., Hopkins, M. G., Nemeth, P. M., Lowry, O. H. & Holloszy, J. O. 1996. Mitochondrial enzymes increase in muscle in response to 7–10 days of cycle exercise. Journal of Applied Physiology 80(6), 2250–2254. doi:10.1152/jappl.1996.80.6.2250.

Spyrou, K., Freitas, T. T., Marín-Cascales, E. & Alcaraz, P. E. 2020. Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review. Frontiers in Psychology 11(), 569897–. doi:10.3389/fpsyg.2020.569897.

Starritt, E. C., Angus, D. & Hargreaves, M. 1999. Effect of short-term training on mitochondrial ATP production rate in human skeletal muscle. Journal of Applied Physiology 86(2), 450–454. doi:10.1152/jappl.1999.86.2.450.

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M. & Milanović, Z. 2017. The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. Sports Medicine 48(1), 111–135. doi:10.1007/s40279-017-0794-z.

Stølen, T., Chamari, K., Castagna, C. & Wisløff, U. 2005. Physiology of soccer: an update. Sports Medicine 35(6), 501–536. doi:10.2165/00007256-200535060-00004.

Suchomel, T. J., Nimphius, S., Bellon, C. R. & Stone. M. H. 2018. The Importance of Muscular Strength: Training Considerations. Sports Medicine 48(4), 765–785. doi:10.1007/s40279-018-0862-z.

Sweeting, A. J., Cormack, S. J., Morgan, S. & Aughey R. J. 2017. When is a Sprint a Sprint? A Review of the Analysis of Team-Sport Athlete Activity Profile. Frontiers in Physiology, 8. doi:10.3389/fphys.2017.00432.

Taylor, J. B., Wright, A. A., Dischiavi, S. L., Townsend, M. A. & Marmon, A. R. 2017. Activity Demands During Multi-Directional Team Sports: A Systematic Review. Sports Medicine 47, 2533–2551. doi:10.1007/s40279-017-0772-5.

Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M. & Monteiro, A. M. 2021. Monitoring Accumulated Training and Match Load in Football: A Systematic Review. International Journal of Environmental Research and Public Health 18(8), 3906. doi:10.3390/ijerph18083906.

Theodoropoulos, J. S., Bettle, J. & Kosy, J. D. 2020. The use of GPS and Inertial Devices for Player Monitoring in Team Sports: A Review of Current and Future Applications. Orthopedic Reviews 12(1). doi:10.4081/or.2020.7863.

Tomlin, D. L. & Wenger, H. A. 2001. The Relationship Between Aerobic Fitness and Recovery from High Intensity Intermitted Exercise. Sports Medicine 31(1), 1–11. doi.10.2165/00007256-200131010-00001.

Twist, P. & Rhodes, T. 1993. Exercise Physiology: The Bioenergetic and Physiological Demands of Ice Hockey. Strength and Conditioning Journal 15(5), 68–70.

Vanrenterghem, J., Nedergaard, N. J., Robinson, M. A. & Drust, B. 2017. Training Load Monitoring in Team Sports: A Novel Framework Separating Physiological and Biomechanical Load-Adaptation Pathways. Sports Medicine 47(11), 2135–2142. doi:10.1007/s40279-017-0714-2.

Varley, M. C., Jaspers, A., Helsen, W. F. & Malone, J. J. 2017. Methodological Considerations When Quantifying High-Intensity Efforts in Team Sport Using Global System Technology, International Journal of Sports Physiology and Performance 12(8), 1059–1068. doi:10.1123/ijspp.2016-0534.

Vasilyev, P., Pearson, S., El-Gohary, M., Aboy, M. & McNames, J. 2017. Inertial and time-of-arrival ranging sensor fusion. Gait & Posture 54, 1-7. doi:10.1016/j.gaitpost.2017.02.011.

Wang, W., Qu, F., Li, S. & Wang, L. 2021. Effects of motor skill level and speed on movement variability during running. Journal of Biomechanics 127, 110680. doi:10.1016/j.jbiomech.2021.110680.

Wedin, J. O. & Henriksson, A. E. 2014. Postgame Elevation of Cardiac Markers Among Elite Floorball Players. Scandinavian Journal of Medicine & Science in Sports 25(4), 495–500. doi:10.1111/sms.12304.

Wernbom, M., Augustsson, J. & Thome, R. 2007. The Influence of Frequency, Intensity, Volume and Mode of Strength Training on Whole Muscle Cross-Sectional Area in Humans. Sports Medicine 37(3), 225–264. doi:10.2165/00007256-200737030-00004.

Yanci, J., Los Arcos, A., Camara, J., Castillo, D., García, A. & Castagna, C. 2016. Effects of horizontal plyometric training volume on soccer players' performance. Research in Sports Medicine 24(4), 308–319. doi:10.1080/15438627.2016.1222.

Zanconato, S., Buchthal, S., Barstow, T. J. & Cooper, D. M. 1993. 31P-magnetic resonance spectroscopy of leg muscle metabolism during exercise in children and adults. Journal of Applied Physiology 74(5), 2214–2218. doi:10.1152/jappl.1993.74.5.2214.

Zhang, S., He, L. & Wu, L. 2020. Statistical Study of Loss of GPS Signals Caused by Severe and Great Geomagnetic Storms. Journal of Geophysical Research: Space Physics. doi:10.1029/2019ja027749.

Ziv, G. & Lidor, R. 2009. Physical Attributes, Physiological Characteristics, On-Court Performances and Nutritional Strategies of Female and Male Basketball Players. Sports Medicine 39(7), 547–568. doi:10.2165/00007256-200939070-00003.

APPENDICES

APPENDIX 1. Table of U18 differences between periods.

VARIABLES	U18 PERIOD 1 Mean ± SD	U18 PERIOD 2 Mean ± SD	U18 PERIOD 3 Mean ± SD	n	p-value[a]
				8	
Shifts (number / game)	7.4 ± 0.5	6.9 ± 0.6	7.6 ± 1.0		0.061
HRmin (bpm)	108.0 ± 11.6	111.1 ± 9.6	110.2 ± 12.1		0.687
HRavg (bpm)	152.1 ± 9.2	147.4 ± 9.3	148.3 ± 10.9		**0.044***
HRmax (bpm)	193.4 ± 8.1	191.9 ± 7.0	191.8 ± 7.1		0.197
HRmin (%)	51.7 ± 4.0	53.2 ± 3.4	52.7 ± 4.0		0.748
HRavg (%)	73.0 ± 3.4	70.7 ± 3.2	71.0 ± 3.5		**0.044***
HRmax (%)	92.9 ± 4.7	92.1 ± 4.1	92.1 ± 3.8		0.508
50–59%/HRmax (min:ss)	03:10 ± 03:00	05:06 ± 03:39	05:42 ± 03:32		**0.010****
60–69%/HRmax (min:ss)	09:59 ± 02:15	12:52 ± 03:20	10:39 ± 02:38		**0.002****
70–79%/HRmax (min:ss)	06:59 ± 02:04	06:14 ± 01:51	06:00 ± 02:01		0.072
80–89%/HRmax (min:ss)	05:55 ± 01:19	05:45 ± 01:18	06:31 ± 01:51		0.197
90–100%/HRmax (min:ss)	02:46 ± 02:39	02:17 ± 02:13	02:16 ± 01:56		0.417
Total Distance (m)	1341 ± 153	1361 ± 161	1321 ± 333		0.882
Average distance (m/min)	46 ± 5	42 ± 5	42 ± 11		0.135
Maximal speed (km/h)	25.4 ± 1.6	25.9 ± 2.4	25.3 ± 1.2		0.607
Average speed (km/h)	2.8 ± 0.3	2.5 ± 0.3	2.5 ± 0.6		0.072
Sprints (qty.)	3.6 ± 1.9	3.7 ± 2.4	3.8 ± 2.1		0.966
Distance in zone 1 (3.00 - 9.99 km/h) (m)	700 ± 59	762 ± 95	727 ± 206		0.197
Distance in zone 2 (10.00 - 13.99 km/h) (m)	307 ± 64	277 ± 55	292 ± 89		0.607
Distance in zone 3 (14.00 - 17.99 km/h) (m)	188 ± 57	174 ± 41	168 ± 45		0.607
Distance in zone 4 (18.00 - 21.99 km/h) (m)	80 ± 33	77 ± 23	67 ± 15		0.325
Distance in zone 5 (22.00- km/h) (m)	34 ± 20	34 ± 24	32 ± 19		0.882
Calories (kcal)	305 ± 31	322 ± 28	313 ± 27		**0.044***
Accelerations 0.50 - 0.99 m/s² (qty.)	60.5 ± 5.9	66.6 ± 5.7	66.2 ± 15.5		0.078
Accelerations 1.00 - 1.99 m/s² (qty.)	74.8 ± 9.0	73.9 ± 14.9	76.3 ± 22.7		0.798
Accelerations 2.00 - 2.99 m/s² (qty.)	26.1 ± 5.0	26.7 ± 4.9	25.5 ± 6.9		0.607
Accelerations 3.00 - 50.00 m/s² (qty.)	0.2 ± 0.3	0.2 ± 0.1	0.1 ± 0.2		0.692
Decelerations –50.00 - –3.00 m/s² (qty.)	6.5 ± 1.9	5.6 ± 1.4	5.6 ± 1.8		0.542
Decelerations –2.99 - –2.00 m/s² (qty.)	19.5 ± 3.7	19.9 ± 4.0	19.5 ± 7.0		0.648
Decelerations –1.99 - –1.00 m/s² (qty.)	80.1 ± 8.7	85.8 ± 10.0	82.5 ± 22.1		0.197
Decelerations –0.99 - –0.50 m/s² (qty.)	66.0 ± 9.4	71.9 ± 9.3	74.5 ± 20.9		0.093

APPENDIX 2. Table of U21 differences between periods.

VARIABLES	U21 PERIOD 1 Mean ± SD	U21 PERIOD 2 Mean ± SD	U21 PERIOD 3 Mean ± SD	n	p-value[b]
				8	
Shifts (number / game)	6.7 ± 0.7	7.1 ± 0.8	7.3 ± 1.7		0.964
HRmin (bpm)	98.8 ± 11.5	105.7 ± 12.9	101.7 ± 16.5		0.093
HRavg (bpm)	143.8 ± 10.3	144.8 ± 9.9	141.7 ± 12.0		0.115
HRmax (bpm)	187.4 ± 9.3	186.0 ± 8.4	188.1 ± 7.1		0.657
HRmin (%)	48.0 ± 6.6	51.2 ± 6.3	49.2 ± 8.2		0.093
HRavg (%)	69.6 ± 5.1	70.0 ± 5.6	68.5 ± 6.5		0.115
HRmax (%)	90.6 ± 4.3	90.0 ± 5.1	91.1 ± 5.2		0.587
50–59%/HRmax (min:ss)	05:43 ± 03:23	06:25 ± 04:53	06:54 ± 05:34		0.417
60–69%/HRmax (min:ss)	09:02 ± 02:14	09:36 ± 01:14	10:15 ± 03:23		0.687
70–79%/HRmax (min:ss)	06:11 ± 01:45	07:24 ± 02:23	06:41 ± 02:24		0.223
80–89%/HRmax (min:ss)	05:18 ± 00:58	05:35 ± 02:17	05:31 ± 02:39		0.417
90–100%/HRmax (min:ss)	01:21 ± 02:33	01:40 ± 02:40	01:39 ± 03:09		0.962
Total Distance (m)	1254 ± 323	1428 ± 241	1403 ± 428		0.417
Average distance (m/min)	44 ± 12	46 ± 8	43 ± 12		0.542
Maximal speed (km/h)	27.2 ± 1.7	26.2 ± 2.5	26.6 ± 1.5		**0.030***
Average speed (km/h)	2.7 ± 0.7	2.8 ± 0.5	2.6 ± 0.7		0.417
Sprints (qty.)	5.4 ± 3.4	5.8 ± 3.9	6.4 ± 4.8		0.419
Distance in zone 1 (3.00 - 9.99 km/h) (m)	604 ± 121	742 ± 99	686 ± 202		**0.030***
Distance in zone 2 (10.00 - 13.99 km/h) (m)	289 ± 121	307 ± 85	295 ± 98		0.687
Distance in zone 3 (14.00 - 17.99 km/h) (m)	200 ± 86	194 ± 69	211 ± 82		0.417
Distance in zone 4 (18.00 - 21.99 km/h) (m)	85 ± 37	99 ± 44	101 ± 56		0.968
Distance in zone 5 (22.00- km/h) (m)	50 ± 31	50 ± 45	74 ± 64		**0.011***
Calories (kcal)	270 ± 37	301 ± 48	306 ± 75		**0.017***
Accelerations 0.50 - 0.99 m/s² (qty.)	50.3 ± 6.8	61.5 ± 7.4	58.4 ± 9.6		**0.002****
Accelerations 1.00 - 1.99 m/s² (qty.)	60.0 ± 14.2	73.2 ± 8.0	73.0 ± 17.9		0.223
Accelerations 2.00 - 2.99 m/s² (qty.)	26.1 ± 8.6	27.0 ± 8.3	27.3 ± 13.1		0.792
Accelerations 3.00 - 50.00 m/s² (qty.)	0.3 ± 0.4	0.5 ± 1.0	0.3 ± 0.5		0.662
Decelerations –50.00 - –3.00 m/s² (qty.)	5.2 ± 2.9	5.9 ± 2.9	5.9 ± 3.2		0.968
Decelerations –2.99 - –2.00 m/s² (qty.)	19.8 ± 5.2	20.4 ± 4.9	20.9 ± 8.1		0.908
Decelerations –1.99 - –1.00 m/s² (qty.)	66.3 ± 13.5	82.5 ± 10.3	79.9 ± 18.6		0.093
Decelerations –0.99 - –0.50 m/s² (qty.)	59.5 ± 13.8	70.8 ± 9.7	65.0 ± 14.7		0.072

APPENDIX 3. Table of men's differences between periods.

VARIABLES	MEN PERIOD 1 Mean ± SD	MEN PERIOD 2 Mean ± SD	MEN PERIOD 3 Mean ± SD	n	p-value[c]
				8	
Shifts (number / game)	7.9 ± 0.5	7.5 ± 1.1	8.3 ± 1.4		**0.014***
HRmin (bpm)	103.0 ± 8.8	110.0 ± 9.8	107.5 ± 11.3		**0.008****
HRavg (bpm)	146.5 ± 8.5	147.5 ± 9.1	148.7 ± 8.8		0.508
HRmax (bpm)	190.1 ± 7.6	188.9 ± 7.3	190.0 ± 6.7		0.508
HRmin (%)	51.1 ± 3.4	54.5 ± 4.0	53.2 ± 4.8		**0.024***
HRavg (%)	72.7 ± 2.7	73.1 ± 3.0	73.8 ± 3.3		0.508
HRmax (%)	94.5 ± 2.0	93.9 ± 1.6	94.3 ± 2.0		0.468
50–59%/HRmax (min:ss)	04:02 ± 03:00	02:55 ± 02:44	03:46 ± 03:33		0.417
60–69%/HRmax (min:ss)	09:13 ± 01:55	10:34 ± 02:10	10:00 ± 02:51		0.417
70–79%/HRmax (min:ss)	06:46 ± 01:21	06:50 ± 01:58	08:18 ± 02:01		0.072
80–89%/HRmax (min:ss)	06:59 ± 00:57	07:13 ± 01:47	08:01 ± 02:08		0.072
90–100%/HRmax (min:ss)	02:27 ± 01:21	02:33 ± 01:05	03:04 ± 01:26		0.687
Total Distance (m)	1372 ± 196	1423 ± 338	1594 ± 419		0.093
Average distance (m/min)	46 ± 7	47 ± 9	48 ± 11		0.882
Maximal speed (km/h)	26.8 ± 0.9	26.8 ± 0.6	27.1 ± 1.7		0.882
Average speed (km/h)	2.8 ± 0.4	2.8 ± 0.5	2.9 ± 0.7		0.607
Sprints (qty.)	6.5 ± 2.9	6.5 ± 2.7	6.8 ± 2.7		0.905
Distance in zone 1 (3.00 - 9.99 km/h) (m)	679 ± 81	731 ± 213	835 ± 237		**0.010****
Distance in zone 2 (10.00 - 13.99 km/h) (m)	285 ± 78	288 ± 102	320 ± 119		0.135
Distance in zone 3 (14.00 - 17.99 km/h) (m)	199 ± 55	199 ± 43	220 ± 60		0.687
Distance in zone 4 (18.00 - 21.99 km/h) (m)	91 ± 34	103 ± 36	107 ± 33		**0.030***
Distance in zone 5 (22.00- km/h) (m)	66 ± 32	66 ± 27	70 ± 31		0.417
Calories (kcal)	379 ± 44	395 ± 73	432 ± 77		**0.030***
Accelerations 0.50 - 0.99 m/s² (qty.)	60.5 ± 7.2	63.3 ± 13.6	69.3 ± 14.1		0.206
Accelerations 1.00 - 1.99 m/s² (qty.)	71.1 ± 11.9	71.5 ± 23.2	85.0 ± 27.4		**0.034***
Accelerations 2.00 - 2.99 m/s² (qty.)	28.4 ± 6.5	28.5 ± 5.9	30.3 ± 7.9		0.687
Accelerations 3.00 - 50.00 m/s² (qty.)	0.4 ± 0.3	0.5 ± 0.5	0.3 ± 0.3		0.565
Decelerations –50.00 - –3.00 m/s² (qty.)	6.9 ± 3.1	7.5 ± 2.7	7.8 ± 3.3		0.798
Decelerations –2.99 - –2.00 m/s² (qty.)	23.2 ± 3.8	22.8 ± 5.5	24.0 ± 5.9		0.508
Decelerations –1.99 - –1.00 m/s² (qty.)	74.8 ± 8.5	76.5 ± 16.4	90.4 ± 24.3		**0.034***
Decelerations –0.99 - –0.50 m/s² (qty.)	65.9 ± 9.1	67.0 ± 18.4	76.0 ± 19.8		0.197

APPENDIX 4. Table of the association matrix of internal and external load variables comparison between levels.

VARIABLES	HRmin (bpm)			HRavg (bpm)			Hrmax (bpm)			HRmin (%)			HRavg (%)		
	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN
Shifts	0.071	0.587	0.262	0.214	**0.683***	0.395	–0.524	**0.671***	0.214	–0.167	0.476	0.048	0.071	0.551	0.500
TD	0.214	0.262	0.310	0.429	0.524	0.407	–0.143	0.476	0.143	–0.071	0.190	0.190	0.381	0.524	0.571
AvgDistance	0.190	–0.048	0.238	0.405	0.262	0.383	–0.071	0.333	0.143	–0.167	–0.048	0.119	0.310	0.333	0.595
MaxSpeed	0.571	**0.643***	**0.643***	0.595	**0.643***	**0.755***	0.524	0.524	0.500	0.190	**0.690***	0.619	0.357	**0.714***	**0.833****
AvgSpeed	0.190	–0.048	0.238	0.405	0.262	0.383	–0.071	0.333	0.143	–0.167	–0.048	0.119	0.310	0.333	0.595
Sprints	0.515	**0.667***	**0.833****	0.599	**0.738***	**0.898****	**0.850****	**0.833****	0.595	0.168	**0.667***	**0.762***	**0.647***	0.595	**0.857****
TDSpeedzone1	0.214	**0.690***	0.024	0.262	**0.667***	0.132	–0.476	0.500	–0.095	–0.048	**0.643***	–0.143	–0.119	**0.714***	0.310
TDSpeedzone2	–0.071	–0.119	0.310	0.262	0.238	0.419	0.095	0.310	0.429	–0.143	–0.119	0.238	0.429	0.310	0.548
TDSpeedzone3	0.095	0.048	0.595	0.476	0.333	**0.695***	0.262	0.452	0.262	0.095	0.095	0.595	**0.643***	0.381	**0.857****
TDSpeedzone4	0.429	0.476	**0.762***	**0.643***	0.595	**0.850****	0.476	**0.690***	0.500	0.286	0.548	**0.738***	**0.881****	0.595	**0.905****
TDSpeedzone5	0.476	**0.762***	**0.833****	0.548	**0.833****	**0.898****	**0.857****	**0.905****	0.595	0.095	**0.714***	**0.762***	0.595	0.619	**0.857****
Accelerations1	0.119	**0.667***	–0.048	0.214	**0.714***	0.048	–0.310	0.524	–0.095	–0.262	**0.643***	–0.214	0.048	**0.762***	0.167
Accelerations2	0.000	0.571	–0.167	0.143	**0.643***	–0.060	–0.310	**0.690***	–0.190	–0.190	0.381	–0.238	–0.071	0.381	0.214
Accelerations3	0.000	0.238	0.595	0.262	0.429	**0.731***	0.143	0.571	0.357	–0.048	0.310	0.476	0.452	0.452	**0.833****
Accelerations4	**0.663***	0.098	**0.719***	0.602	0.268	**0.795****	0.157	0.366	0.599	0.482	0.122	**0.623***	0.060	0.366	**0.731***
Decelerations1	0.286	**0.690***	**0.690***	0.381	**0.786***	**0.802****	**0.810****	**0.881****	0.405	–0.071	**0.690***	**0.643***	0.571	0.619	**0.905****
Decelerations2	0.167	**0.667***	0.405	0.381	**0.690***	0.515	–0.048	**0.690***	0.286	0.024	**0.667***	0.238	0.143	**0.690***	0.619
Decelerations3	0.286	0.381	0.024	0.452	0.595	0.132	–0.043	**0.738***	–0.095	–0.048	0.214	–0.143	0.286	0.310	0.310
Decelerations4	0.333	0.524	0.095	0.405	0.619	0.228	–0.333	0.548	0.071	0.000	0.467	0.024	0.143	0.619	0.476

VARIABLES	HRmax (%)			50–59%/HRmax (min:ss)			60–69%/HRmax (min:ss)			70–79%/HRmax (min:ss)			80–89%/HRmax (min:ss)			90–100%/HRmax (min:ss)		
	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN	U18	U21	MEN
Shifts	–0.190	0.563	–0.262	–0.071	–0.611	–0.143	**–0.690***	0.096	–0.119	0.429	0.575	0.619	0.476	0.192	**–0.857****	–0.238	0.539	–0.238
TD	0.071	0.429	–0.310	–0.357	–0.595	–0.238	**–0.667***	–0.381	0.143	0.405	–0.024	**0.786***	0.524	0.310	**0.929****	0.071	0.190	–0.190
AvgDistance	0.024	0.357	–0.214	–0.262	–0.381	–0.190	**–0.643***	**–0.667***	–0.048	0.357	–0.333	**0.667***	0.381	0.286	**0.833****	0.024	0.333	–0.071
MaxSpeed	–0.214	**0.762***	0.310	–0.333	**–0.786***	**–0.667***	0.405	0.190	–0.167	0.357	0.619	0.381	–0.476	0.524	0.381	–0.071	**0.762***	0.429
AvgSpeed	0.024	0.357	–0.214	–0.262	–0.381	–0.190	**–0.643***	**–0.667***	–0.048	0.357	–0.333	**0.667***	0.381	0.286	**0.833****	0.024	0.333	–0.071
Sprints	0.299	**0.643***	0.333	–0.587	–0.524	**–0.857****	0.323	–0.119	0.143	0.108	0.381	0.476	–0.323	0.476	0.571	0.419	**0.905****	0.452
TDSpeedzone1	–0.476	**0.714***	–0.476	0.000	**–0.690***	0.071	–0.524	0.238	–0.190	0.405	**0.690***	0.571	0.467	0.333	**0.762***	–0.500	0.500	–0.405
TDSpeedzone2	0.381	0.333	0.048	–0.286	–0.357	–0.262	**–0.714***	–0.548	0.524	0.143	–0.429	**0.667***	0.500	0.333	**0.810****	0.429	0.310	0.119
TDSpeedzone3	0.381	0.405	0.048	–0.476	–0.333	**–0.643***	–0.548	**–0.762***	0.048	0.333	–0.405	**0.690***	0.452	0.429	**0.714***	0.524	0.500	0.310
TDSpeedzone4	0.452	**0.643***	0.286	**–0.810****	–0.381	**–0.810****	–0.024	–0.452	0.095	0.262	–0.024	0.548	0.190	0.595	0.595	0.595	**0.833****	0.476
TDSpeedzone5	0.310	0.619	0.333	–0.524	–0.619	**–0.857****	0.310	0.000	0.143	0.071	0.524	0.476	–0.381	0.429	0.571	0.405	**0.833****	0.452
Accelerations1	–0.286	**0.738***	–0.405	0.000	**–0.714***	0.143	–0.310	0.524	–0.095	0.286	0.548	0.476	–0.048	0.548	**0.690***	–0.286	0.524	–0.357
Accelerations2	–0.333	0.333	–0.452	0.095	–0.429	0.214	–0.405	–0.048	–0.024	0.190	0.548	0.524	0.167	–0.048	**0.643***	–0.286	0.310	–0.333
Accelerations3	0.405	0.524	0.024	–0.381	–0.286	–0.571	–0.548	**–0.643***	–0.119	0.024	–0.238	**0.667***	0.524	0,500	**0.810****	0.452	**0.738***	0.190
Accelerations4	**–0.663***	0.537	0.419	–0.205	–0.293	**–0.743***	0.349	–0.415	–0.084	0.602	–0.024	0.192	–0.096	0.268	0.311	–0.506	**0.683***	0.467
Decelerations1	0.429	0.619	0.143	–0.405	–0.548	**–0.714***	0.310	–0.190	0.024	–0.024	0.310	**0.667***	–0.571	0.524	**0.738***	0.500	**0.857****	0.357
Decelerations2	–0.119	**0.738***	–0.214	–0.167	–0.429	–0.310	**–0.667***	–0.119	0.119	0.357	0.333	**0.762***	0.619	0.476	**0.952****	–0.071	**0.762***	–0.143
Decelerations3	–0.071	0.310	–0.476	–0.310	–0.381	0.071	–0.524	–0.071	–0.190	0.333	0.262	0.571	0.429	0.071	**0.762***	–0.048	0.452	–0.405
Decelerations4	–0.357	**0.667***	–0.262	–0.214	**–0.714***	–0.048	–0.333	0.143	0.119	0.429	0.548	**0.690***	0.286	0.333	**0.810****	–0.333	0.619	–0.119

$p < 0.05$*, $p < 0.01$** and $p < 0.001$***. Statistical differences are seen as bolded values. TD = total distance. AvgDistance = average distance travelled during shifts. AvgSpeed = average speed during shifts. TDSpeedzone1 = total distance travelled in speedzone 3.00–9.99 km/h. TDSpeedzone2 = total distance travelled in speedzone 10.00–13.99 km/h. TDSpeedzone3 = total distance travelled in speedzone 14.00–17.99 km/h. TDSpeedzone4 = total distance travelled in speedzone 18.00–21.99 km/h. TDSpeedzone5 total distance travelled in speedzone >22.00 km/h). Accelerations1 = accelerations between 0.50–0.99 m/s². Accelerations2 = accelerations between 1.00–1.99 m/s². Accelerations3 = accelerations between 2.00 – 2.99 m/s². Accelerations4 = accelerations between 3.00–50.00 m/s². Decelerations4 = decelerations between –50.00 - –3.00 m/s². Decelerations3 = decelerations between –2.99 - –2.00 m/s². Decelerations2 = decelerations between –1.99 - –1.00 m/s². Decelerations1 = decelerations between –0.99 - –0.50 m/s².