PHYSICAL PERFORMANCE OF FINNISH FUTSAL PLAYERS, ANALYSIS OF INTENSITY AND FATIGUE IN OFFICIAL FUTSAL GAMES

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ABSTRACT

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Introduction. Futsal has grown notably in last years and have over 12 million players worldwide. Futsal is a high-intensity indoor sport where burst of multi-planar movements varies with short periods of rest. Futsal is played on a court sized 40 x 20 m for two halves of 20 min, where clock is stopped when ball is out of play. Purpose of this study was to find out physical performance of Finnish futsal players and analyse intensity and fatigue in official futsal games.

Methods. Two Finnish Futsal League teams were involved (n = 19), age 26.3 (± 3.0 years), body mass 76.4 (± 6.2 kg), height 178.7 (± 5.7 cm), BMI 23.9 (± 1.4 kg/m^2) and body fat % 12.3 (± 4.0 %). Measurement were done in the middle of the season 2016-2017, during two months' period. Two games from both teams were analysed. Measuring included physical performance tests (sprint test 5-m and 20-m, agility test, CMJ, isometric leg press and maximal treadmill running test) and game measurements (HR, movement distances and velocities, playing time, accelerations and deceleration). CMJ and lactate were measured before, middle and after futsal game to assess fatigue.

Results. Sprint times were 1.03 (± 0.04 s) in 5-m and 3.01 (± 0.07 s) in 20-m. Agility test time was 6.87 (± 0.25 s). CMJ result was 41.8 (± 5.6 cm) and isometric leg press 5327 (± 1070 N). In the maximal treadmill running test HRmax was 191.6 (± 9.5 bpm), VO2max 59.8 (± 5.4 ml/kg/min) and VEmax 171.9 (± 20.8 l/min). Futsal players moved on average 4463.0 (± 1169.3 m) on intensity 54.0 (± 13.2 m/min) during the futsal games. Sprinting occurred on average 39.7 (± 17.2) times in the games. HRmax achieved during the futsal games was 191.6 (± 9.9 bpm), and average HR 147.0 (± 16.9 bpm). Fatigue did not occur during or after the futsal games when measured as CMJ or lactate ($p > 0.05$).

Conclusions. From the results of the physical performance tests, it seems that Finnish futsal player's physical fitness is comparable to play futsal in high level. During Finnish Futsal League games the distance moved is similar to those measured in literature, but the intensity lower when expressed as % HRmax, distance moved in one minute or in different speed zones. Because fatigue was not evident during the games, higher-intensity tactic or less substitutions to the key players could be used. In general, consistency in research methods would ease comparison of different studies. More futsal research is needed to understand the fundamentals of the sport that is growing and evolving constantly.

Key words: futsal, team sports, maximal oxygen uptake, match analysis, heart rate

LIST OF THE ABBREVIATIONS

BPM	beats per minute
CMJ	countermovement jump
HR	Heart rate
HRmax	Maximal heart rate
MMOL	millimole
RSA	repeated sprint ability
SD	standard deviation
VE	ventilation
VEmax	maximal ventilation
VO2max	maximal oxygen uptake
VT	ventilatory threshold

CONTENTS

1 INTRODUCTION

Futsal is a high-intensity indoor sport where short sprints and change of directions alternate with short periods of rest for a rather long time. Futsal is played 5 vs 5 including goalkeeper in an indoor court sized 40 x 20 m. The playing time is 2 x 20 min with a break between the halves, and the clock is stopped when ball is out of play. Therefore, the playing time is 75-85 % longer than 40 min. (Barbero-Alvarez et al. 2008.) The amount of substitutions is unlimited, and therefore allows for longer recovery times during the game, when necessary.

Futsal requires both good aerobic endurance for recovery during the game breaks, and good repeated sprint ability (RSA) during the game (Castagna et al. 2009). VO2max values between 55-60 ml/kg/min have been measured from professional futsal players (Beato et al. 2016). HR during the game is over 85 % of HRmax for 83 % of time, and seldom drops under 150 bpm (Barbero-Alvarez et al. 2008). Values are higher compared to football, handball or basketball, and highlights the high-intensity nature of professional futsal.

The purpose of this study was to measure whether the game intensity drop in official Finnish Futsal League matches, does the speed and strength qualities decrease during or after the game, and to find out the current physical fitness level of Finnish futsal players. Two Finnish Futsal League team's players concluded a pattern of physical performance tests during the season for the assessment of physical fitness. Both teams were measured in two Finnish Futsal League home games. The measurements in game included continuous HR monitoring, accelerometer, CMJ and lactate measurements before, during and after the game.

2 FUTSAL AS A GAME

2.1 Rules of the game

Futsal is an intermittent team sport played in indoor court sized 40 x 20 m for two 20 minute periods with a half-time between (Barbero-Alvarez et al. 2008). The goal is sized 3 x 2 m, the same size as in handball. At the same time, there is one goalkeeper and four on-field players on the court (Barbero-Alvarez et al. 2008). The team has 9 substitute players who can be used with unlimited number of substitutions. Instead of the clock running all the time, it is stopped when the ball is out of play, and therefore the total match time is usually 75-85 % longer than 40 min (Barbero-Alvarez et al. 2008).

The history of futsal starts from the 1930 with the aim of playing football in a limited space (Barbero-Alvarez et al. 2008). Futsal is played in over 100 countries in the world including more than 12 million players (Beato et al. 2016). The sport has gained popularity in the recent years, including the FIFA Futsal World Cup since 1989 (Beato et al. 2016). Futsal is governed by FIFA (Fédération Internationale de Football Association), the same organization as in football. Despite the rising popularity of futsal, it is often left with less attention compared to football, especially in women's and children's game. Also, the scientific literature from futsal is still little.

2.2 Technical aspects of futsal

Futsal has many similarities to other indoor team sports such as basketball and handball, the main difference being that the ball is controlled with the feet instead of the hands. With the outdoor team sports futsal shares similarities with football, but despite the general assumption, futsal and football have many differences in technique, and futsal has many sport specific techniques that do not display in football. These techniques include using sole of the foot, toe kick, loops and faint movements.

Sole of the foot. In a limited space the ball must be kept closer to feet which is easier with the sole of the foot compared to inside or outside of the foot. Sole of the foot is used for taking the ball over, turning, dribbling and for fake shots (Autio 2015, 176) and differentiates a good futsal player from another.

Toe kick. Toe kick is used for shooting the ball and sometimes for passing. Toe kick can be shot either from a small space or from a high speed running easier than for example instep kick (Autio 2015, 178). Fast toe kick is difficult for the goalkeeper to react or for the defender to block the shot. Spanish national futsal team used toe kick for 15.6 % of time, and scored 14.9 % of their goals with the toe kick in UEFA Euro 2010 tournament (Lapresa et al. 2013).

Loop. Loop, or the aerial ball, in futsal differs from the loop in football. In futsal, the touch time to ball is longer, and the ball lifts without a spin (Autio 2015, 180). The intention of the loops is a pass from the corner kick, or to lift the ball over a goalkeeper who is covering the goal (Autio 2015, 180). Loops can also be used as a parallel pass behind the opponent player in to an empty space (Autio 2015, 180).

Faint movements. Because of the limited space and therefore limited time, the player's must perform sport specific techniques to win time and space in the court. Different faint movements are one way to do so. Faint movements are fast changes of directions and pumping movements, where the idea is first to move in one direction, and then quickly change the direction and usually also the speed of movement. (Autio 2015, 181.) One way to use faint movements is to create a stationary block for a defender, similar to seen in basketball.

Another major difference between futsal and football is the type of movement performed during the game. Australian national futsal team players moved 23.8 % of the total distance side or backways, which counts for almost one fourth of the game (Dogramaci et al. 2011). In their previous study, the distance moved side or backways was 23.9 % for match-time and 28.1 % in clock-time analyses, respectively (Dogramaci & Watsford 2006). In football, the time moved backwards accounted only for 3.7 % in top-class football players, and even less for moderate level players (2.9 %) (Mohr et al. 2003).

Limited space and a small number of players on the futsal court forces movements to be adjusted, so that the player sees the ball, other players and their movements all the time. This requires moving either side or backways, without losing the eye contact to the court. This was highlighted in the study by Dogramaci et al. (2011) which showed that Australian national futsal team players side and backways movement was almost double as much as recreational futsal players (1016 vs 527 m and 23.8 % vs 17.5 % of time from the total distance moved). In football, professional players moved also more backwards compared to moderate level players (Mohr et al. 2003), but the percentages were much lower compared to futsal.

2.3 Tactical aspects of futsal

The basic principle of futsal is to score goals to win the game, which is universal to all team sports. Tactic means the common plan of the team where the players execute agreed and trained actions (Autio 2015, 182). Futsal is a highly tactical game which emphasizes that there are only four on-field players and that the ball is touched with the feet in limited space. Playing systems in futsal can be divided to offensive and defensive playing. Offensive and defensive plays change repeatedly during the game, depending on which team has the ball in control. In general, it is easier to score goals when the team is in possession of the ball and attacking.

Defensive playing can be divided to man marking or zonal defence, and either to a high or low pressure. Man marking in defence means that each defender guards his own player as long as needed. In zonal defence, each player has an area and passing lines that they are trying to cover, instead of simply following an offensive player. Offensive playing systems are usually marked as numbers, the most common ones being 2-2, 3-1 and 4-0. (Autio 2015, 184-185.) Goalkeepers are usually excluded from these markings. Table 1 shows both the strength and weaknesses of different offensive playing systems.

TABLE 1. Different offensive playing systems in futsal, their strengths and weaknesses and to who they are suitable for. Adopted from Autio (2015, 184-187).

Playing systems	Strengths	Weaknesses	Good for
2-2	good balance in the court depth is well used	long distances between players running out of passing lines	junior teams
3-1	target playing easy to adopt	needs a good pivot player	teams with a good pivot
4-0	long ball controlling a lot of passing options	depth is not always well used requires a lot from the players	professional teams

Futsal playing positions are a goalkeeper, defender, winger and pivot. In many team sports, different playing positions have different physical requirements, depending on the playing system and tactic of the team. However, in futsal all playing positions have more similar requirements between each other, compared to other team sports such as football or basketball, where the playing position heavily effects the movement. Caetano et al. (2015) found no differences in sprint characteristics among different positions in futsal. Sprinting distances, durations, peak velocities, initial velocities, recovery time between sprints and sprints per minute had no statistical differences between the different on-field playing positions (Caetano et al. 2015). In another study, there were also no differences between playing positions in the distance moved or in the percentage of distance moved in different intensities (Barbero-Alvarez et al. 2008). In both previously mentioned studies, goalkeepers were excluded. For on-field players in futsal it seems that the distance and intensity of the movements are similar, regardless of the playing position (Barbero-Alvarez et al. 2008).

3 PHYSICAL PROFILE OF A FUTSAL PLAYER

Game analysis is needed to understand the fundamentals of the sport. Game analysis provides precise researched information of a sport, that can be then used for example coaching. In this chapter, futsal player's physical fitness is presented. The chapter is divided to anthropometry of a futsal player, endurance in futsal and strength and power in futsal.

3.1 Anthropometry of a futsal player

Table 2 lists futsal on-field players age, height and weight measured in different studies. It seems from table 2 that there are no special body size requirements for playing futsal. The body fat percentages of futsal players have ranged from low 9.7 (± 2.5 %) and 10.0 (± 2.4 %), up to rather high 17.3 (± 3.7 %) (Gorostiaga et al. 2009; Rodrigues et al. 2011; Charlot et al. 2016). In the study by Rodrigues et al. (2011) the body fat percentage decreased from the 10.0 (± 2.4 %) measured preseason, to 9.6 (± 2.4 %) postseason.

TABLE 2. Futsal on-field players' age, height and weight from different studies.

Nationality	Age (years)	Height (cm)	Body mass (kg)	Reference
Spain	25.6 ± 2.5	175.0 ± 6.0	73.8 ± 5.7	Barbero-Alvarez et al. (2008)
Spain	26.2 ± 4.1	176.7 ± 7.6	76.9 ± 10.0	Gorostiaga et al. (2009)
Brazil	23.9 ± 5.4	176.4 ± 5.8	74.5 ± 8.1	Baroni & Leal Junior (2010)
Australia	25.5 ± 3.8	176.0 ± 7.0	74.8 ± 4.7	Dogramaci et al. (2011)
Brazil	22.5 ± 3.1	172.8 ± 5.5	70.0 ± 6.3	Rodrigues et al. (2011)
Thailand	24.2 ± 5.0	174.0 ± 3.0	66.9 ± 4.5	Makaje et al. (2012)
Brazil	26.0 ± 4.0	175.0 ± 6.0	73.0 ± 7.8	De Oliveira Bueno et al. (2014)
New Caledonia	25.5 ± 3.8	170.0 ± 7.0	70.7 ± 8.6	Charlot et al. (2016)

Baroni & Leal Junior (2010) compared Brazilian futsal goalkeepers (n = 22) to on-field players n = 164). Futsal goalkeepers were on average longer (180.04 ± 5.47 cm vs. 176.36 ± 5.75 cm) and heavier (85.95 ± 10.23 kg vs. 74.48 ± 8.11 kg), compared to on-field players. Futsal goalkeepers may have different requirements compared to on-field players, since part of intercepting the ball going to the goal is to block the shots. Extra height and weight may give some advantage for goalkeepers to be in front of the ball when shot is taken.

3.2 Endurance in futsal

Futsal is a running game. The total distance covered during a futsal game ranges from around 3000 m up to over 6000 m (De Oliveira Bueno et al. 2014; Hernandez et al. 2001). Factors affecting the wide range of distances measured are different player levels, different tactics and different measurement techniques. Therefore, comparing solely the distance covered during a game gives a little information about the physiology of futsal. Also, as Barbero-Alvarez et al. (2008) points out, in a sport with unlimited substitutions the distance cannot be considered as a performance indicator, as in sports like football or rugby where substitutes are limited. Better indicator would be the movement intensity expressed as m/min, because it tracks only the actual time on the court. From the table 3, it seems that the intensity (m/min) has raised in the last decade. Barbero-Alvarez et al. (2008) suggest that rise in the intensity means increase in the physiological requirements in futsal. Developments in the game such as offensive 4-0 playing system and defensive high-pressuring tactic may have contributed to the increase in the game intensity (Barbero-Alvarez et al. 2008).

TABLE 3. Covered distances during futsal games and intensities reported as m/min.

Reference	1st half (m)	2nd half (m)	Whole match (m)	Intensity (m/min)
Hernandez (2001)			6535.3	
Barbero-Alvarez et al. (2008)	2496.1 ± 1024.9	2595.7 ± 932	4313.2 ± 2138.6	117.3 ± 11.6
Castagna et al. (2009)				121 ± 8.2
Dogramaci et al. (2011)			4277 ± 1030	139.8
Makaje et al. (2012)			5087 ± 1104	
De Oliveira Bueno et al. (2014)	1710.6 ± 888.3	1635.9 ± 1089.2	3133.2 ± 2248.5	94.1 ± 14.1

Figure 1 shows movement intensities during a futsal game. Over half of the total movement takes place at medium intensity (10.9-18.0 km/h), high intensity (18.1-25.0 km/h) or sprinting (over 25.1 km/h). This percentage is greater than in basketball, handball or football (Barbero-Alvarez et al. 2008), which highlights the intensity of movement in futsal. Work to rest ratio is close to 1:1 on the court, where half of the movement is executed at high intensity, and half either walking or jogging. Sprinting distance during the game is almost 9 % of the total moved distance, approximately 350 m during the futsal game (Barbero-Alvarez et al. 2008).

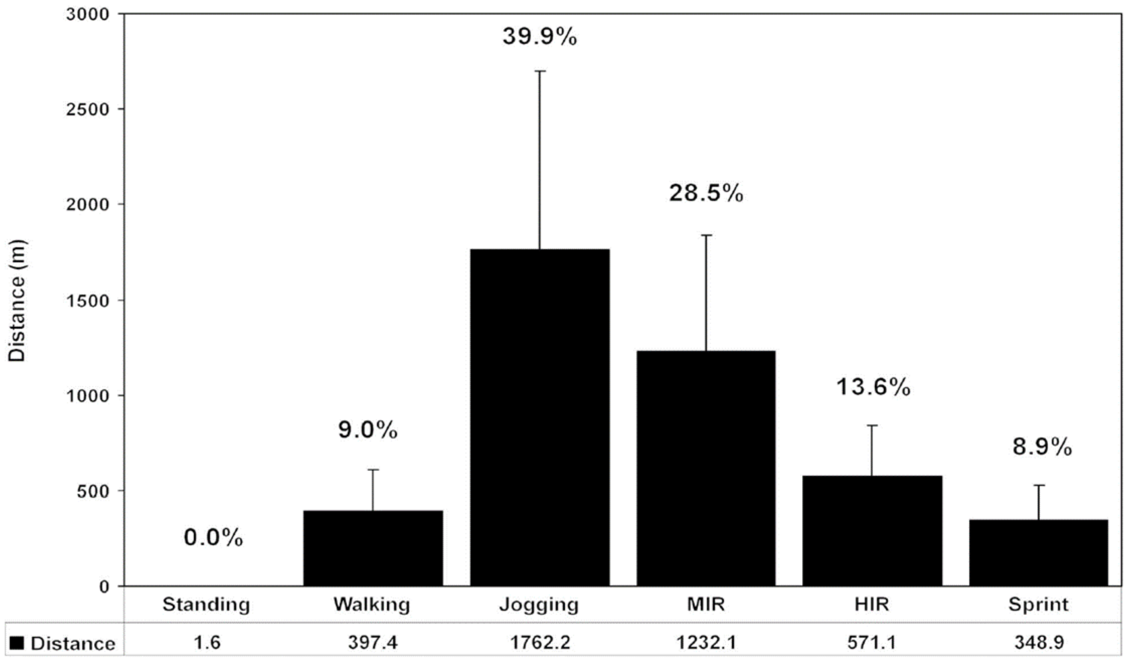


FIGURE 1. Movement intensities in percentages, standard deviations and mean distances in futsal matches. MIR = medium intensity running. HIR = high intensity running. Adopted from Barbero-Alvarez et al. (2008).

In 5 official futsal games in the Brazilian First Division Futsal League, the average number of sprints during a game was 26 (± 13.3) (Caetano et al. 2015). The average distance of the sprint was 13.3 m (± 5.7 m) and 14.0 m (± 6.5 m) in the first and the second half, respectively, without a difference between the two halves (Caetano et al. 2015). Sprint duration differed between the halves (3.1 s ± 1.2 s vs 3.2 s ± 1.3 s, $p < 0.05$) (Caetano et al. 2015). Average recovery time between the sprint was 55.3 s (± 60.5 s) in the first half and 63.2 (± 71.6 s) in the second half, with no difference between the two halves (Caetano et al. 2015). The large standard deviations in the recovery times mean, that sometimes sprints occurred in sequences, depending on the game situation. Repeated sprints included either two (85.9 %), three (11.6 %) or four (2.5 %) sprints at one time (Caetano et al. 2015).

In another study, during a simulated match play (4 x 10 min), athletes performed 7.2 sprints (range 1.5-12.9) in each period, average sprinting distance was 10.5 m (range 6.2-14.8 m) and average sprinting time was 1.95 s (range 1.4-2.5 s) (Castagna et al. 2009). Sprint took place approximately every 79 s, but in 54 % of the time the recovery between sprints was less than 40s (Castagna et al. 2009). Average sprinting distance in futsal seems to be 10-14 m and the average sprinting time 2-3 s.

Because of the high-intensity actions in futsal, heart rates (HR) are high. HR is over 85 % of HRmax for 83 % of the playing time, and seldom drops under 150 bpm (Barbero-Alvarez et al. 2008). Rodrigues et al. (2011) measured Brazilian players during official league games, and the average intensity was 86.4 (± 3.8 %) of maximal HR (HRmax). The HR also reached 199.8 (± 8.5 bpm) during the futsal games, which was significantly higher compared to HRmax of 191.0 (± 8.7 bpm) measured in maximal treadmill running test (Rodrigues et al. 2011). During a simulated training games (4 x 10 min), average HR was 90 % (range 84-96 %) and peak HR was 98 % (range 90-106 %) from the values measured in maximal treadmill running test (Castagna et al. 2009).

Traditionally the VO2max value has been the indicator for aerobic performance. According to Castagna et al. (2009) futsal players need a good aerobic fitness to play in the high level. This means a relatively high VO2max value between 55-60 ml/kg/min, which allows better recovery during the game breaks and when player is resting on the bench (Álvarez et al. 2009; Castagna et al. 2009; Beato et al. 2016). VO2max values high as 71.5 ± 5.9 ml/kg/min has been reported in professional futsal players (Rodrigues et al. 2011). Repeated sprint ability (RSA) is a futsal specific demand (Castagna et al. 2009). Multiple sprint sequences with little or no rest take place during the game (Castagna et al. 2009). Ventilatory threshold (VT), sometimes named as anaerobic threshold (AT) or lactate threshold (LT), is the point when ventilation increases exponentially with concurrent increase in the work intensity (Plato et al. 2008). VT values have been between 67.5-71.0 % of VO2max in professional futsal players (Castagna et al. 2009; Álvarez et al. 2009; Pedro et al. 2013). These values were lower compared to football players, even though futsal players had higher VO2max relative to weight (Leal Junior et al. 2006).

Repeated sprints and high blood lactate levels mentioned earlier, may point out that anaerobic metabolism is involved during a futsal play (Castagna et al. 2009). Muscle and blood lactate levels may temporarily rise when the game intensity is high and there is no breaks or rest time for the player. Mean blood lactate values during simulated futsal game were 5.3 mmol/l (range 1.1-10.4 mmol/l) measured with random blood sampling (Castagna et al. 2009). Partly high blood lactate levels may point out the involvement of anaerobic metabolism during futsal, when multiple high intensity actions are executed with little or no recovery in between (Castagna et al. 2009). Blood lactate values differed between elite and amateur futsal players

(5.5 ± 1.4 and 5.1 ± 1.5 mmol/l, respectively), which was supported by the higher involvement in high intensity actions by the elite players during simulated futsal game compared to the amateur players (Makaje et al. 2012). Temporarily blood lactate values may rise over 10 mmol/l in futsal game, but are more likely to stay close to values of 5 mmol/l.

Endurance capacity seems to be, at least partly, a disjunctive factor in the futsal playing level. Table 4 summarizes studies comparing endurance performance in futsal players of different levels. In a study by Álvarez et al. (2009) playing level discriminated both VO2max and VO2 at VT values. In another study, VO2max was clearly higher for elite players compared to amateurs (Makaje et al. 2012). The same difference was found between professional women players compared to sport students (Karahan et al. 2012). Pedro et al. (2013) found no difference in either VO2max or VO2 at VT values between professional and semi-professional Thai players. However, professional players could run faster at VO2max (17.5 ± 0.9 vs 15.2 ± 1.0 km/h) and at VO2 at VT (11.2 ± 1.0 vs 10.0 ± 1.2 km/h) compared to semi-professional players (Pedro et al. 2013). This points out that the ability to run faster at similar VO2 values may be an important factor for team sport players (Pedro et al. 2013).

TABLE 4. VO2max and VO2 at VT values from different futsal studies, comparing playing level. * = statistically significant difference between groups in the same study.

Playing level (country)	VO2max (ml/kg/min)	VO2 at VT (ml/kg/min)	How measured	Reference
Professional (Spain)	62.8 ± 5.3	44.4 ± 4.6	Treadmill	Álvarez et al. (2009)
Semi-professional (Spain)	55.2 ± 5.7*	39.1 ± 4.0*	Treadmill	
Professional (Brazil)	63.7 ± 4.1	43.0 ± 4.1	Treadmill	Pedro et al. (2013)
Semi-professional (Brazil)	62.1 ± 4.4	44.0 ± 3.8	Treadmill	
Elite (Thailand)	60.4 ± 5.1	-	Treadmill	Makaje et al. (2012)
Amateur (Thailand)	57.2 ± 6.2*	-	Treadmill	
Professional women (Turkey)	39.5 ± 1.0	-	Multi-stage run test	Karahan et al. (2012)
Sport students women (Turkey)	34.2 ± 1.4*	-	Multi-stage run test	

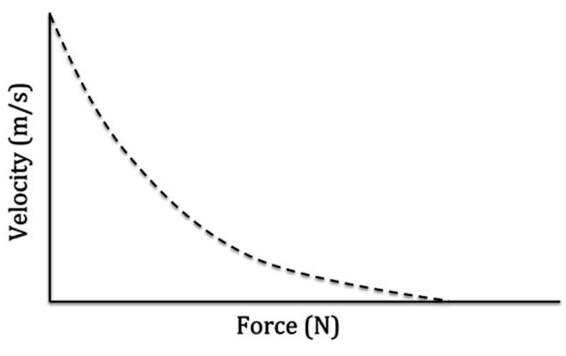
3.3 Strength and power in futsal

Strength can be defined as the maximal force that muscle or muscle group can produce and is associated with sport performance e.g. better sprinting performance and aerobic endurance performance (Bompa & Haff 2009, 261). Increasing half-squat strength in elite football players improved the 10-m sprint time over an 8-week training period (Helgerud et al. 2011). The widely-accepted benefits of strength training for team sport players are a reduced risk of injury and improved endurance performance (Gamble 2013, 75-76). Bompa & Haff (2009, 263-265) list factors that affect strength:

- motor unit (MU) recruitment
- MU rate coding
- MU synchronization
- stretch shortening cycle (SSC)
- neuromuscular inhibition
- muscle fiber type
- muscle hypertrophy

Power is the product of force and velocity, or work performed in time (Bompa & Haff 2009, 262-263). The interaction between force and velocity is often described with the force-velocity curve (figure 2A), where force (N) is in the x-axel and velocity (m/s) is in the y-axel. In the velocity end of the curve the external load (or resistance) is low and the velocity high, whereas in the force end of the curve the external load is high and the velocity low. Force-velocity curve can be altered with heavy or explosive resistance training (Bompa & Haff 2009, 262). Theoretically heavy resistance training increases the high-force portion of the curve, and explosive resistance training increases the high-velocity portion of the curve as in figure 2B (Bompa & Haff 2009, 262).

A)



B)

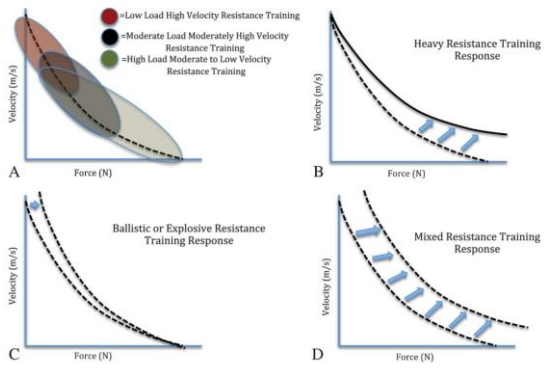


FIGURE 2. A: Force-velocity curve. B: changes in force-velocity curve from training. Adopted from Haff & Nimphius (2012).

In futsal both strength and power are required for sport specific actions such as accelerations, decelerations, sprinting, change of directions, kicking and tackling. Gorostiaga et al. (2009) compared professional football and futsal players from Spain, and reported that football players demonstrated higher vertical jumping height, faster sprinting (5-m and 15-m) and higher concentric half-squat power. Futsal players had lower muscle power both in absolute and relative levels, which may compromise the ability to endure forceful muscle contractions during the game (Gorostiaga et al. 2009). No differences were noticed between the groups in endurance running (Gorostiaga et al. 2009), even though both sports have different requirements regarding endurance performance.

Table 5 summarizes futsal player's strength and power results from the literature. The most common tests seem to be a countermovement jump (CMJ) and short sprints (5, 10 and 20 m). Half-squat has also been used (Gorostiaga et al. 2009). Because the average sprinting distance in futsal is approximately 10-14 m (Castagna et al. 2009; Caetano et al. 2015), testing sprinting distances over 20 m is not sport specific. Large SD in CMJ results in table 5 is probably due to different jumping protocols used in the studies. Lack of more comprehensive presentation of futsal player's strength and power results is partly explained by the general paucity of futsal literature, and calls for more research.

TABLE 5. Summary of futsal player's strength and power capabilities. Results are mean ± SD.

Team level (country)	CMJ (cm)	5 m time (s)	10 m time (s)	20 m time (s)	Reference
Professional team (Spain)	38.1 ± 4.1	1.01 ± 0.02	-	-	Gorostiaga et al. (2009)
Professional team (Brazil)	39.2 ± 4.4	1.05 ± 0.04	1.78 ± 0.06	3.05 ± 0.10	Nakamura et al. (2016)
U20 team (Brazil)	39.9 ± 4.3	0.99 ± 0.05	1.69 ± 0.07	2.92 ± 0.10	Nakamura et al. (2016)
National team (New Caledonia)	-	1.00 ± 0.07	1.72 ± 0.07	-	Charlot et al. (2016)
Elite team (New Zealand)	52.1 ± 4.2	1.00 ± 0.04	1.75 ± 0.03	2.99 ± 0.04	Naser & Ali (2016)
Semi-elite team (New Zealand)	49.9 ± 3.9	1.06 ± 0.02	1.78 ± 0.01	3.05 ± 0.04	Naser & Ali (2016)

4 SMALL-SIDED GAMES

Small-sided games (SSG) are widely researched as a mean to promote the physical and technical side of a professional football players. The SSGs are usually played between 3 vs 3 players up to 11 vs 11 players, changing the playing size according to the number of players. Since the research in futsal is limited, SSG research may help to assist understand the requirements in futsal game play, especially when executed in environment that imitate futsal. There are limitations in SSG research when applied to futsal, for example in the number of players or in the playing surface.

4.1 Significance in the number of players

Owen et al. (2014) divided different sized small-sided games in to small (SSG; 4 vs 4), medium (MSG; 5 vs 5 to 8 vs 8) and large (LSG; 9 vs 9 to 11 vs 11) according to number of players involved and alteration in the court size. Their main findings were that SSGs involved faster playing speed compared to MSGs and LSGs, but less repeated high-intensity efforts, high-intensity running and sprint distance compared to LSGs (Owen et al. 2014). On the technical side, in the SSGs more passes, receives, dribbles and shots were made, compared to both MSGs and LSGs (Owen et al. 2014). There was also more passes and shots in the MSGs compared to the LSGs, and less headers in both SSGs and MSGs compare to the LSGs (Owen et al. 2014).

In another study, more tackles and shots occurred when the court size was reduced and the number of players remained the same (Kelly & Drust 2009). From the research, it can be concluded that the number of players has significant impact on both physical and technical side in SSGs. It seems, that smaller the number of players and the court, the more involved the players are on technical side (Aguiar et al. 2012). Also, the game intensity is higher expressed as m/min. However, the amount of high-intensity running is increased when the playing area is increased, which may be due to longer distances to pressure the opponent or moving to free areas to receive pass (Owen et al. 2014). Smaller court size forces players for more comprehensive participation to the game in high intensity, but at the same time the amount of maximal velocity running decreases because the distances are shorter.

Kelly & Drust (2009) found mean HRmax in three different court sizes to be 204 (± 9 bpm) in young elite football players, and mean HR values did not change when the court size varied. In all court sizes the exercise intensity was 89 % of HRmax, or higher (Kelly & Drust 2009). In a review of SSGs ranking from 3 vs 3 up to 6 vs 6 players, the HR values ranked between 83-90 % of HRmax (Aguiar et al. 2012). Mäkelä (2001) measured average HR of 87.1 % of HRmax in Finnish football players during a SSG. Previous HR values in SSGs are similar to those found in futsal games. In the study by Kelly & Drust (2009) the number of players remained the same (4 vs 4) and the court size changes only a little, so it can be classified as SSG. When SSGs are compared to LSGs the HR responses area higher and the time spend in the > 85 % HRmax zone is longer (Owen et al. 2014; Owen et al. 2011). This was also reviewed by Aguiar et al. (2012) that reducing the court size and number of the players evoked greater HR responses. However, they pointed out typical error in variability of less than 5 % in SSG studies, which has produced no differences in few studies when the court size or number of players have been altered too little (Aguiar et al. 2012).

4.2 Limitations of SSG studies

There are several limitations in applying SSG research to futsal. The first one is the use of different number of players and court sizes that does not necessarily match those in futsal. In futsal, the number of players is 5 vs 5 including the goalkeepers, and the court is 40 m x 20 m (FIFA 2015). Therefore, the playing area in futsal is 800 m^2, and the court ratio per player is 1:80 (m^2). For example, Owen et al. (2014) used court ratios of 1:94 (4 vs 4, 30 m x 20 m), 1:184 (5 vs 5, 46 m x 40 m) and 1:183 (6 vs 6, 50 m x 40 m), that are all greater than in futsal. If the court ratio per player doubles from futsal, conclusions from the SSGs applied to futsal are hard to come by. Kelly & Drust (2009) tested three different court sizes (30 m x 20 m, 40 m x 30 m and 50 m x 40 m), while keeping the number of players the same (4 vs 4). This made a court ratio per player 1:75, 1:150 and 1:250, respectively (Kelly & Drust 2009). They found that altering court size had no effect on HR responses, but changes the number of technical actions, just as increasing the number of tackles and shots in the smaller court (Kelly & Drust 2009). Table 6 summarizes different types of SSGs and different number of players and court sizes used. In overall, when the court ratio per player increases too much, the nature of SSGs goes too far from futsal.

TABLE 6. Different formats, court sizes, surface areas and court ratios per player in futsal, small-, medium- and large-sided games.

Classification	Format	Pitch size	Surface area	Pitch ratio per player	Reference
Futsal	5 vs 5	40 x 20 m	800 m^2	1:80	FIFA (2015)
Small-sided game	4 vs 4	30 x 25 m	750 m^2	1:94	Owen et al. (2014)
	4 vs 4	30 x 25 m	750 m^2	1:94	Owen et al. (2011)
	4 vs 4	30 x 20 m	600 m^2	1:75	Kelly & Drust 2009)
	4 vs 4	40 x 30 m	1200 m^2	1:150	Kelly & Drust 2009)
	4 vs 4	50 x 40 m	2000 m^2	1:250	Kelly & Drust 2009)
	5 vs 5	40 x 30 m	1200 m^2	1:120	Mäkelä (2001)
Medium-sided game	6 vs 6	50 x 44 m	2200 m^2	1:183	Owen et al. (2014)
Large-sided game	10 vs 10	60 x 50 m	3000 m^2	1:150	Owen et al. (2011)

The second limitation is different playing surface used in futsal and SSGs. Futsal is played indoor either in a wooden parquet or in an artificial/synthetic surface (FIFA 2015). Football and SSGs are played outdoor in a natural grass (Owen et al. 2014). Details of the effects of different surfaces are not discussed here, but it may affect the movement patterns of the players. Also, futsal ball is smaller compared to ball in football, and has 30 % less bounce (Benvenuti et al. 2010), which may affect the technical side of the game and research, such as the number of headers and passes.

The third limitation in comparing futsal and SSGs relates to time. Futsal is played for two periods of 20 min where clock is stopped when ball is out of play (FIFA 2015). SSG research is usually played in intervals, for example 3 x 5 min with 3 min passive recovery (Owen et al. 2014) or 9 x 2 min with 1 min passive recovery (Mäkelä 2001). In futsal, the natural breaks happen when ball is out of play or the player is substituted, and are unpredictable. The work to rest ratio alters HR responses and the game intensity, which are important variables when studying futsal. For these reasons, futsal game studies and controlled SSG studies cannot fully be compared, but SSG studies complete the lack of futsal literature when the limitations in applying SSG studies are known.

5 FATIGUE DURING AND AFRER A FUTSAL GAME

5.1 Neuromuscular fatigue

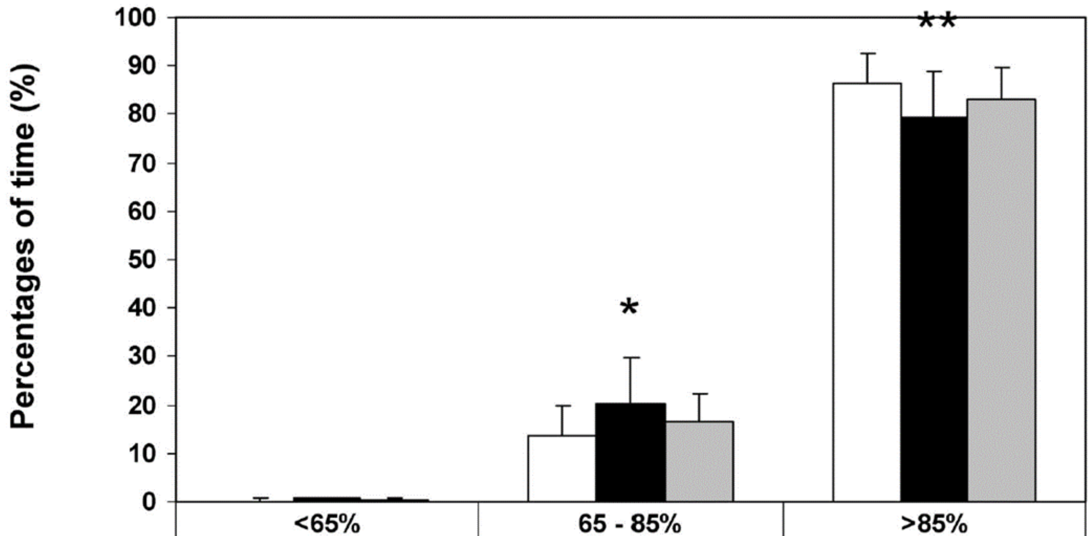
Fatigue is defined to be exercise based phenomenon, where muscles ability to produce force or power is reduced, regardless whether the current task can be maintained or not (Enoka 2008, 317). Usually fatigue starts soon after beginning of the task, even though the task can still be performed (Barry & Enoka 2007). To keep the desired force or power level, the perceived effort increases, before it starts to decline (Enoka & Stuart 1992). During a 4-day futsal tournament, perceived effort increased but the game intensity did not vary from game to game (Charlot et al. 2016). Fatigue can rise from the muscle or from the neural level, and thus includes the whole motor system (Enoka & Stuart 1992). Fatigue impairs both neural and muscular mechanics, and is divided into a central (neural) and a peripheral (muscular) fatigue (Barry & Enoka 2007). For this reason, the term neuromuscular fatigue is used.

Instead of a single mechanism that would produce fatigue, it seems that the fatigue is task dependent (Enoka & Stuart 1992; Barry & Enoka 2007). Also, from the study by Häkkinen & Myllylä (1990), it seems that fatigue, and recovery from it, is result from prolonged training. Authors tested endurance, strength and power athletes to maintain isometric force production at 60 % of their maximum level. Endurance athletes took longest time to fatigue, and had smaller decreases in maximal force, maximal rate of force production and relaxation, compared to strength and power athletes. At the beginning, endurance athletes had the lowest and slowest rate of force production to begin with, whereas power athletes had the highest and fastest. (Häkkinen & Myllylä 1990.) Training in a sport specific way help the players to endure fatigue during futsal games.

5.2 Fatigue in a futsal game

In futsal, there is unlimited number of substitutions during the game. One team can have 5 players on the court (a goalkeeper and 4 on-field players), and 9 players on the bench (FIFA 2015). With the unlimited substitutions, there is opportunity to give players more time to recover if necessary. Possible mechanisms causing fatigue during futsal can be thermal stress, dehydration or reduction in glycogen stores (De Oliveira Bueno et al. 2014). One simple way to prevent fatigue and decrease in physical performance is to substitute players more during the game (De Oliveira Bueno et al. 2014). However, the tendency is that 6-8 key players play most of the time, and that the number of substitutes are restricted by the coach to maximize the success in the game. The same was noted in elite female handball, where the key players were exposed to extensive playing time, and therefore heavier physical loads and thus fatigue in international tournament (Ronglan et al. 2006).

From the previous reasons and the analysis of high-intensity efforts in futsal, it could be expected that players experience certain level of fatigue during the game. In figure 3, more time is spent in HR zone 65-85 % of HRmax and less time in HR zone > 85 % of HRmax in the second half compared to the first half (Barbero-Alvarez et al. 2008). However, only a small decrease in distance of high intensity running (from 13.9 % to 12.9), and a small increase in walking (from 8.6 % to 10.0 %) was noticed between the first and the second half (Barbero-Alvarez et al. 2008). The distance of jogging, medium intensity running and sprinting stayed the same between the two halves (Barbero-Alvarez et al. 2008).



	<65%	65 - 85%	>85%
□ First Half	0.2	13.5	86.2
■ Second Half	0.6	20.1	79.4
▩ Average Futsal	0.3	16.4	83.2

FIGURE 3. Percentage of time spend in different HR zones during the game. Adopted from Barbero-Alvarez et al. (2008).

The mean HR was statistically lower ($p < 0.001$) in the second half (172 bpm, 88.1 % of HRmax) than in the first half (176 bpm, 91.1 % of HRmax) as seen in figure 4 (Barbero-Alvarez et al. 2008). Also, HR was lower in the second half as percentage of time in HR zones 170-180 bpm (30.6 % vs 29.2 %), 180-190 bpm (34.4 % vs 30.2 %) and 190-200 bpm (12.4 % vs 7.2 %), but higher in HR zone 150-160 bpm (5.3 % vs 9.6 %) (Barbero-Alvarez et al. 2008).

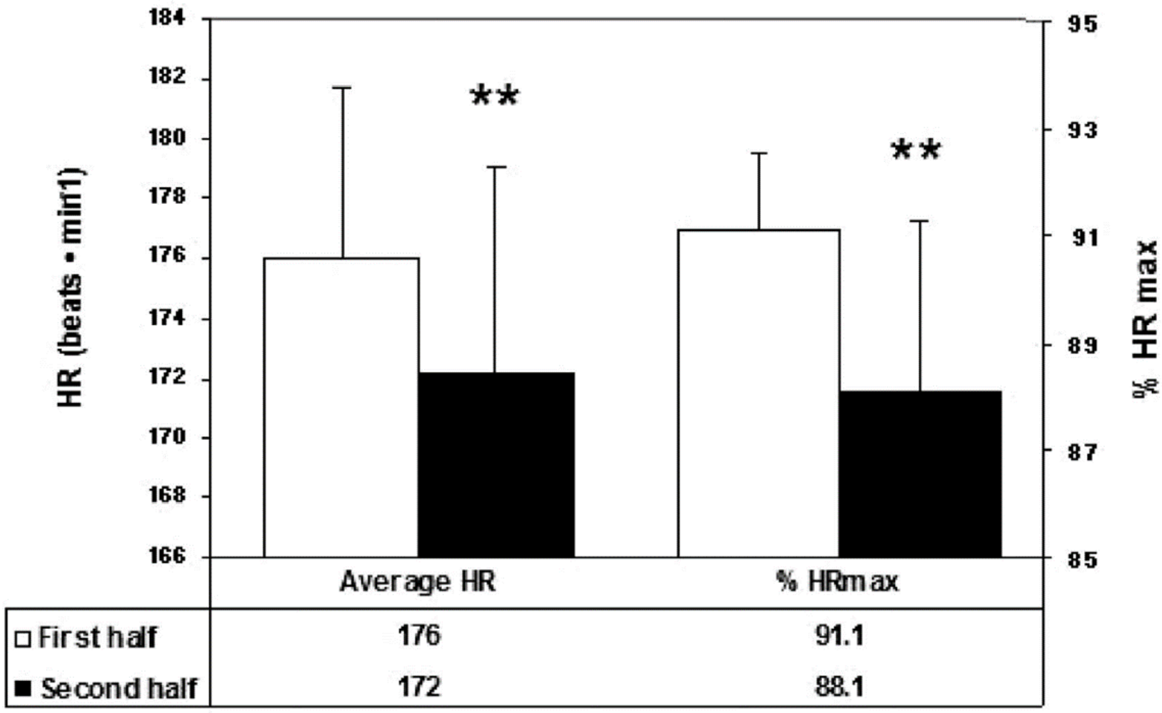


FIGURE 4. Changes in average HR and % HRmax between the first and the second half during a futsal game. Adopted from Barbero-Alvarez et al. (2008).

In a previously mentioned study by Barbero-Alvarez et al. (2008) the distances covered during a futsal game was 2496 m (range 754-4395 m) and 2596 m (range 400-4395 m) in the first and second half, respectively (figure 5), and had no statistical difference. Athletes were recorded in four official league games, where differences in playing time may explain the large ranges in the total distances (Barbero-Alvarez et al. 2008). In study by De Oliveira Bueno et al. (2014), the distance covered between the two halves did not differ being 1710.6 ± 888.3 in the first half and 1635.9 ± 1089.2 in the second half, respectively.

As in figure 5, the distance covered between the two halves was not statistically significant, but the relative distance, or intensity, (m/min) reduced significantly from 118.4 m/min to

110.5 m/min from the first to the second half decreasing by 7.1 % (Barbero-Alvarez et al. 2008). The same was noted by De Oliveira Bueno et al. (2014), where intensity decreased from 97.9 (± 16.2 m/min) in the first half to 90.3 (± 12.0 m/min) in the second half (table 3 before). Also, a decrease from the first to the second half in medium- and high-intensity running was noted, and increase in standing and walking, all measured in moved distance ($p < 0.01$) (De Oliveira Bueno et al. 2014). The overall distance between the halves seems to be relatively same, but the game intensity is decreased towards the end of a futsal game as a result of fatigue.

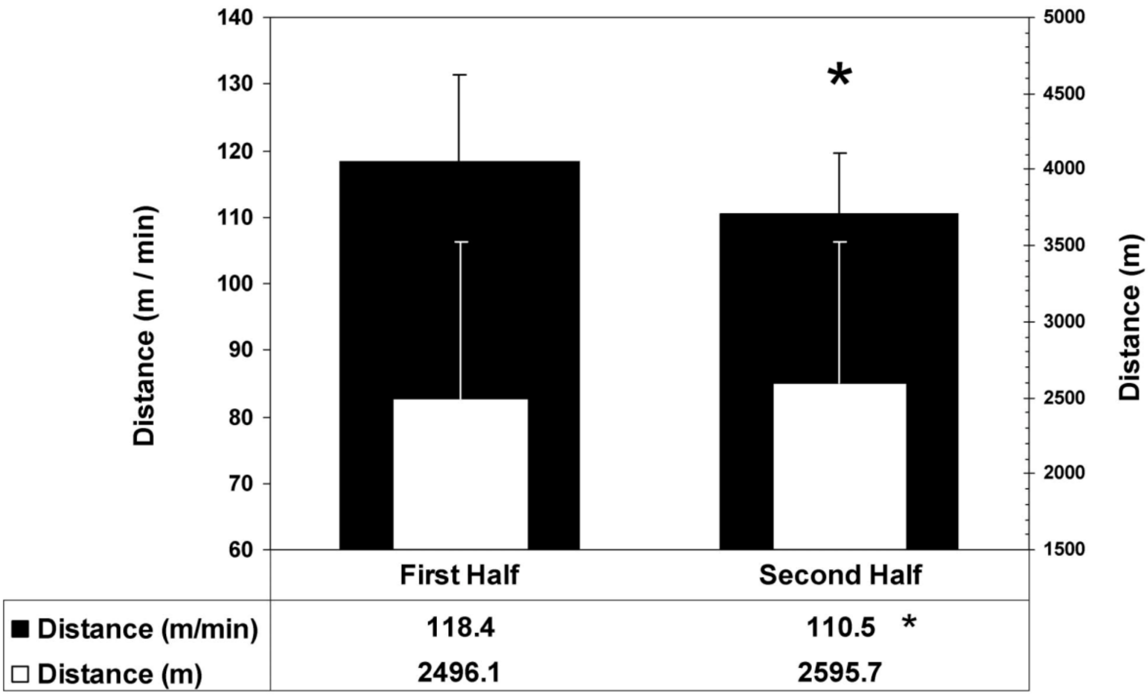


FIGURE 5. Mean distance (m) and relative distance (m/min) covered during a futsal games first and second half. Adopted from Barbero-Alvarez et al. (2008).

Fatigue is inevitable at some point of the game, but the effects of fatigue to performance in team sports are harder to study. Fatigue causes minor reduction in maximal jump height and sprint performance in handball players, but how this affects the game performance is questionable (Ronglan et al. 2006). As Ronglan et al. (2006) discuss, handball consists of technical, tactical and psychological skills additionally to physical capacity. The same applies to futsal and other team sports. Few studies in futsal suggest that the game intensity is dropped in the second half, pointing to the neuromuscular fatigue (De Oliveira Bueno et al.

2014; Barbero-Alvarez et al. 2008). High-intensity actions are partly compensated by walking or jogging in low-intensity (De Oliveira Bueno et al. 2014; Barbero-Alvarez et al. 2008).

5.3 Recovery from a futsal game

Futsal games are sometimes played in consecutive days, for example in international tournaments there are 0-2 recovery days between the games (Charlot et al. 2016). In normal league competitions, matches are usually played once a week. These different playing rhythms are assumed to have different recovery mechanics, but research of a weekly futsal matches is limited. In one study, player’s fitness level was monitored through the whole season (Rodrigues et al. 2011). VO2max and weight remained the same, whereas the body fat percentage decreased from the beginning to the end of the competition season (Rodrigues et al. 2011). Elite futsal players maintained their physical fitness during three months in-season measured as YoYo IR1 and RSA tests, and improved their RSA best time (Oliveira et al. 2013).

Freitas et al. (2014) studied the fatigue over a 4-day tournament in professional male futsal players. They found a decrease in power production (squat jump and countermovement jump, CMJ) through the tournament, and a drop in two recovery questionnaires (RESTQ-Sport scales) from pre to post tournament, suggesting cumulative fatigue during the tournament (Freitas et al. 2014). In another study of an international FIFA tournament, lasting 4 days with 4 futsal games, the authors found no or only minor changes in match intensity HR, recovery kinetics or well-being (Charlot et al. 2016). The perceived exertion (RPE) increased slightly during the tournament, but did not affect the game intensity or recovery from the games (Charlot et al. 2016). Elite female handball players were tested in a 5-day training camp to assess the neuromuscular fatigue from training, and in a 3-day international tournament to find out the neuromuscular fatigue from handball games played in three consecutive days (Ronglan et al. 2006). Performance decreased 2-8 % in the training camp (isokinetic knee extension peak torque, CMJ and 20-m sprint time), and 4-7 % in the international tournament (CMJ and 20-m sprint time) (Ronglan et al. 2006).

Decrease in performance from an intense training camp is desirable, if it is proceeded with a recovery period. Interestingly, in the study by Charlot et al. (2016), futsal player’s performance stayed levelled in an intense tournament, but handball player’s performance decreased (Ronglan et al. 2006). Obviously, handball is different sport compared to futsal, although sharing many similarities (court size, goal size, intensive indoor sport). Further research of acute and long term recovery in futsal games is needed to fully understand the role of neuromuscular fatigue in the sport. Specially measuring acute fatigue during after the futsal games needs to be examined.

Berdejo-del-Fresno & Laupheimer (2014) tested the recovery and regeneration patterns of English national team futsal players before and during a training camp (1-week period; 3 day out, 1 day travelling, 3 day in) with the TQR (total quality recovery) questionnaire and urine osmolality status. Players recovery status was much better in the camp than before the camp (TQR questionnaire), and the travelling day to the camp gave the lowest score in the TQR questionnaire (Berdejo-del-Fresno & Laupheimer 2014). Based on the urine osmolality, half of the player's hydration status was inadequate during the training camp (Berdejo-del-Fresno & Laupheimer 2014).

Not only is fatigue and recovery important for game success. Injury risk is higher when players are more fatigued, usually during the latter parts of the game (Gamble 2013, 153). Futsal has relatively high injury rates, and about two thirds of the injuries involved contact with other player, and one third of the injuries happened without contact (Junge & Dvorak 2010; A. Hamid et al. 2014). Most of the injuries happened in the lower extremities, ankle being the most usual part for injury (Junge & Dvorak 2010; A. Hamid et al. 2014). All injuries that happen without contact and are due to excess fatigue could be considered unnecessary. Understanding better the sport specific physical requirements, training and playing can be adjusted better to avoid excess fatigue, and maybe reduce injuries from non-contact situations.

6 MATCH ANALYSIS SYSTEMS IN TEAM SPORTS

Two different match analysis systems are shortly reviewed here which are widely used in the team sports, and in this thesis, namely accelerometers and video analysis. Different analysis systems can be used either individually or combined, when more data is possibly obtained. For example, combining integrated accelerometer and video analysis system for tracking players. Advances in technique is currently faster than what the research can catch up, and therefore validation of the new systems is lacking behind.

6.1 Accelerometer

Accelerometers work triaxially in three planes (x = vertical movement, y = antero-posterior or front-to-back movement, z = medio-lateral or side-to-side movement) (Krasnoff et al. 2008). Accelerometers recognize movement frequencies and magnitudes, and they have some advantages over other match analysis systems:

- Accelerometers can be used both indoor and outdoor sports
- Possibility to tracking multiple athletes at once
- Inclusion of skill and contact aspect of team sports
- Accelerometers are small, wireless and portable
- Minimal irritation to the athlete

(Krasnoff et al. 2008; Li et al. 2016; Boyd et al. 2011)

The importance of the validity of accelerometers is to find out how output varies for different activities and intensities (Welk 2005). Wundersitz et al. (2015a; 2015b) tested the validity of the accelerometer in physical collisions, and in peak accelerations during walking, jogging and running. Unfiltered accelerometer data overestimated the peak impact accelerations when compared to the motion-analysis system (Wundersitz et al. 2015a; 2015b). From different cutoff filters, 20 Hz frequency produced the best relationship with the motion-analysis system during physical collisions (Wundersitz et al. 2015a), and the cutoff filter of 10 Hz produced the best accuracy with the motion-analysis system in walking, jogging and running

(Wundersitz et al. 2015b). It seems that filtered accelerometer provides an acceptable level of accuracy in peak acceleration during walking and jogging (Wundersitz et al. 2015b), and when measuring physical collisions in contact sports (Wundersitz et al. 2015a).

Reliability studies focus on the interunit function of different accelerometer units (Welk 2005). The importance of the interunit reliability is emphasized in practice when devices change from athlete to athlete, as is normal in team sport setting. Boyd et al. (2011) showed good reliability for 8 MinimaxX 2.0 accelerometers during static and dynamic conditions in laboratory and in Australian football games field testing. In another study, 22 RT3 Triaxial Accelerometers showed poor between unit reliability, but excellent within-unit reliability (Krasnoff et al. 2008). Therefore, it seems that accelerometers have some limitations. Within-subject errors come from biological variations (displacement of the accelerometer, different body shapes, gait biomechanics and/or movement) and device measurement errors (Krasnoff et al. 2008).

6.2 Video analysis

The video analyses in team sports can be divided to live-observations and post-event analysis, called notational analysis. The notational analyses require always manual work and only few athletes can be tracked at once. There are commercial systems available that are said to be automatic, but involve also manual steps (e.g. filtering), and research data from these systems is non-existing. (Barris & Button 2008.) Different stages of the video analysis are shown in figure 6 (Barbero-Alvarez et al. 2008). Almost all steps in the figure 6 involve manual work.

Edgecomb & Norton (2006) compared the GPS system and computer-based video analyzing systems in Australian football. The video analyzing system produced a systematic error of overestimation of the travelled distance (Edgecomb & Norton 2006). Also, the GPS system overestimated the distance, but little less than the video analyzing system (Edgecomb & Norton 2006). The authors concluded that both systems produce a small error of overestimation, but are valid tools for measuring distance in team sports (Edgecomb & Norton 2006). Duthie et al. (2003) found the video analysis to be fairly reliability for measuring rugby players’ movement patterns.

Dogramaci & Watsford (2006) compared different methods of the time-motion analysis in futsal. In the clock-time method, only active game time is counted and all breaks are excluded, such as ball out of play, time-outs, injuries and half-time. Match-time analysis includes all activities from kick-off until full-time, only excluding time-outs and the half-time. (Dogramaci & Watsford 2006.) In futsal, this means 40 minutes of analyse in clock time, and around 70 minutes of analyse in match time, depending on the length of the breaks during the game.

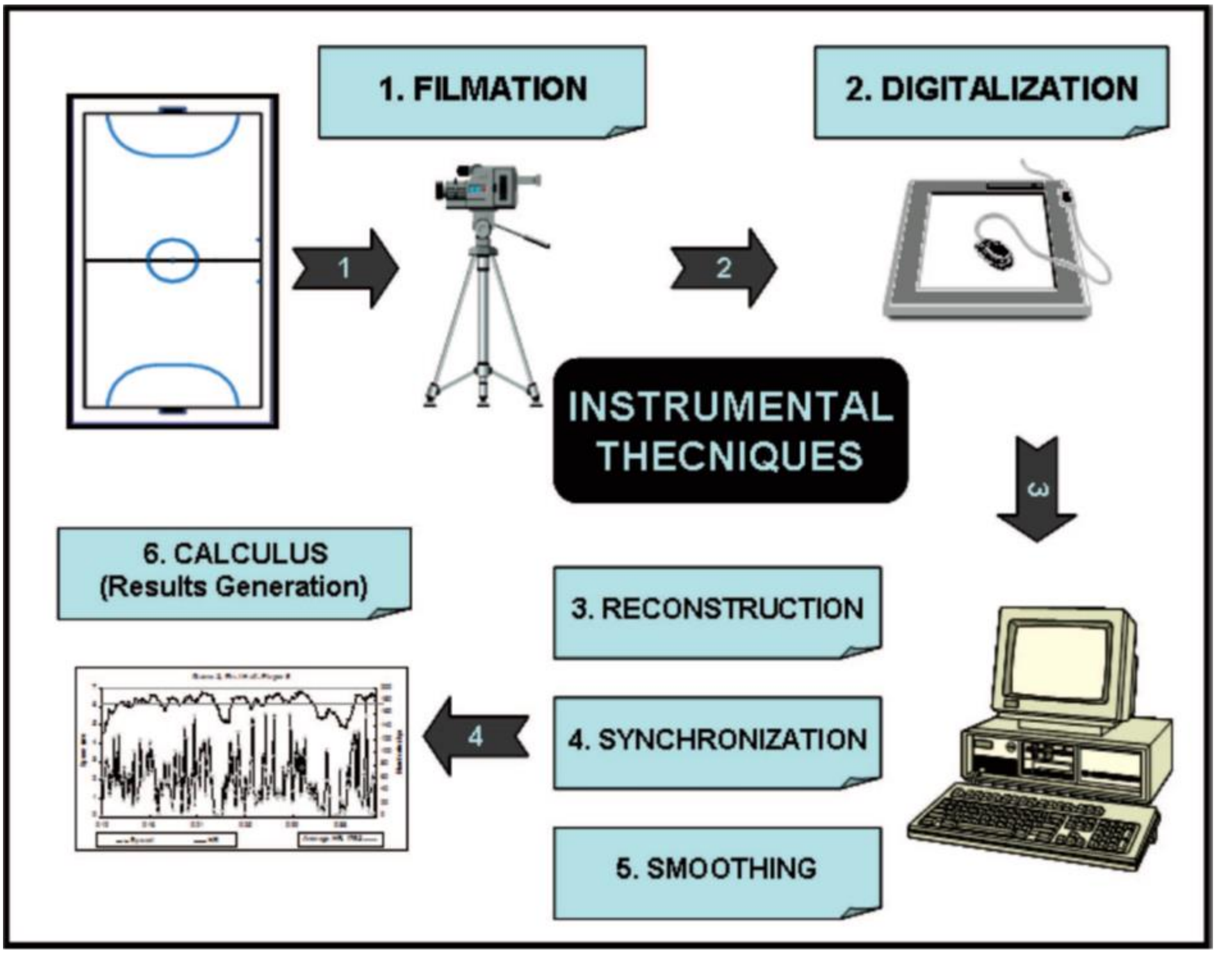


FIGURE 6. Methodological stages of the video analysis. Adopted from Barbero-Alvarez et al. (2008).

When clock-time and match-time data were compared, there was a small decrease in the high intensity actions during the futsal game (running 4.4 %, sprinting 0. 49 % and side/backways 4.6 %), which suggest that clock-time consist of the high intensity actions, and match-time includes the natural low intensity actions during the game (Dogramaci & Watsford 2006). Both the walking and jogging distances and durations, and standing durations increased from the clock-time to the match-time (Dogramaci & Watsford 2006). Athletes are trying to maximize the recovery during the game breaks, and are not performing any excessive high intensity actions. Concluding from the study by Dogramaci & Watsford (2006) it seems that the clock-time method may give false representation of the movement patterns in a futsal game.

7 RESEARCH QUESTIONS AND HYPOTHESES

1) Does the game intensity drop between the first and the second period of the game?

Hypothesis: the game intensity drops because of neuromuscular fatigue.

Answer: Barbero-Alvarez et al. (2008) found out that the intensity (m/min) dropped from the first half to the second half from 118.4 m/min to 110.5 m/min. They also found that the amount of high-intensity running (HIT) decreased to the second half, and at the same time distance walked increased (Barbero-Alvarez et al. 2008). The same was noted by De Oliveira Bueno et al. (2014), where intensity decreased from 97.9 m/min in the first half to 90.3 m/min in the second half. On the other hand, Caetano et al. (2015) found no changes between the two halves in distance covered sprinting, peak sprint velocity, initial sprint velocity or number of sprints in minute.

2) Does the speed and strength qualities decrease during or after the futsal game?

Hypothesis: Players capacity to produce force may decrease during the futsal game, or after the game during recovery.

Answer: Freitas et al. (2014) found a gradual decrease in power production (squat jump and countermovement jump) during a 4 successive days of futsal games. Caetano et al. (2015) found no changes in sprinting variables between the halves during futsal games. In elite female handball 3-day international tournament caused a 4-7 % decrease in the performance measured as CMJ and 20-m sprint time (Ronglan et al. 2006).

3) What is the physical performance of a Finnish Futsal League player?

Hypothesis: Based on research data available, Finnish Futsal League player's physical qualities are comparable to an international level.

Answer: Futsal player's aerobic fitness (VO2max) is measured to be between 55-60 ml/kg/min, or higher (Castagna et al. 2009; Álvarez et al. 2009; Beato et al. 2016). Professional futsal players ran 1226-1507 in the YoYo Intermittent Recovery Test, level 1 (YoYo IR1) (Nakamura et al. 2016; Oliveira et al. 2013; Boullosa et al. 2013). Aerobic fitness seems to be disjunctive factor in competition level in futsal (Álvarez et al. 2009; Pedro et al. 2013). Also, ability to repeat sprints with a short recovery is very futsal specific ability (Castagna et al. 2009). Professional futsal players CMJs were between 38.1-39.2 cm and 5-m sprint times between 1.01-1.05 s (Gorostiaga et al. 2009; Nakamura et al. 2016).

8 METHODS

8.1 Participants

Nineteen Finnish male futsal players from two different Finnish Futsal League teams participated in the study (n = 19). Goalkeepers were excluded from all the data analysis because of the low number of participation. In the previous season of 2015-2016 the other team placed fifth in the regular season, and the other team was a runner-up in the Finnish Futsal Cup. Five of the players has been, or currently, is in the Finnish futsal national team. Therefore, the players can be considered top level in Finland. Anthropometry of the players is presented in table 7. Body mass and Body fat % were measured with automatic InBody770-device, and analysed with LookingBody-software. BMI was calculated from the body mass and height.

TABLE 7. Anthropometry of the futsal players. Mean ± SD.

Age (years) (n = 19)	Body mass (kg) (n = 19)	Height (cm) (n = 19)	BMI (kg/m^2) (n = 19)	Body fat (%) (n = 19)
26.3 ± 3.0	76.4 ± 6.2	178.7 ± 5.7	23.9 ± 1.4	12.3 ± 4.0

Both teams trained futsal 3-5 times a week plus including on average one game during the season. They also did physical training 1-2 times a week, usually combined to the futsal training sessions. Informed written consent was obtained from all players and the participation to the study was voluntary. Players had the possibility to withdraw from the study at any point. Pre-information and health-questionnaire was filled in the first meeting (appendix 1).

8.2 Study design

The study was conducted in the middle of the 2016-2017 futsal season. All the measurements were done between November and December 2016, as seen in figure 7. The measurements included physical performance tests for each player, and game measurements during official Finnish Futsal League games. Physical performance tests were divided in to two sessions (figure 7). Sprint and agility tests were carried out for the whole team in one session before their own futsal training. Other tests (CMJ, isometric leg press and maximal treadmill running test) all players performed independently.

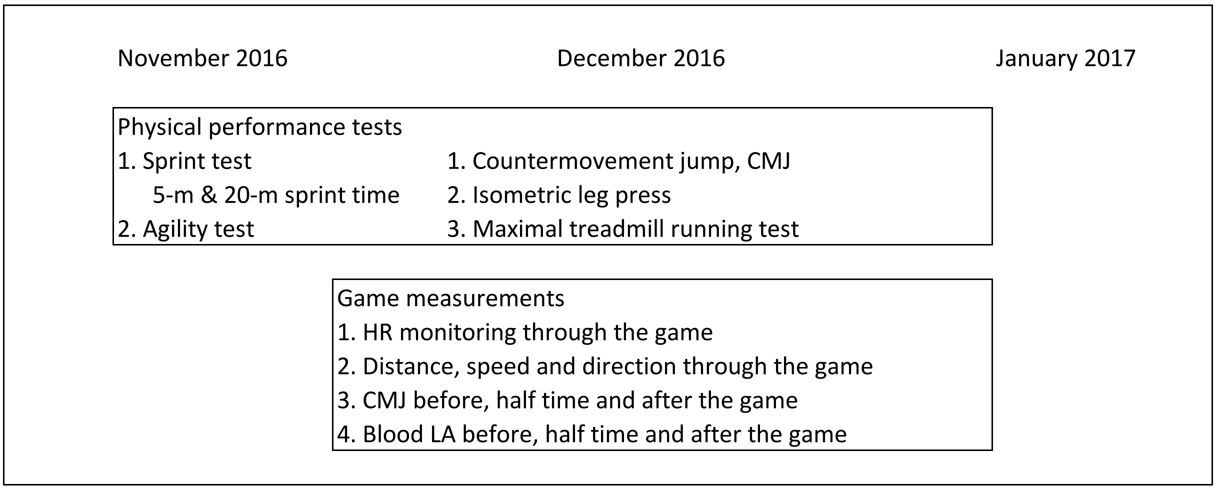


FIGURE 7. Timetable and outline of the measurements in the study.

Physical performance tests. The sprint test included 5-m and 20-m split times which are distances usually measured in futsal (Gorostiaga et al. 2009; Nakamura et al. 2016; Naser & Ali 2016). Longer sprints than 20 m happened seldom in futsal (Caetano et al. 2015). The agility test included a specific track (appendix 2), where the player started and ended in the same line. The purpose of the agility test was to assess the players change of direction (COD) ability. Both tests included two attempts and the best time was recorded. The time was recorded with one-hundred of second accuracy with photocells placed to the waist level. In both tests starting line was 0.7 m behind the first photocell to ensure that no additional movement would trigger the timing (appendix 2). Both teams performed the sprint and agility tests once at agreed time before their normal futsal training.

The rest of the physical performance tests were done separately from other training, each player individually. The test times were decided in collaboration with the player and the researcher to ensure that the player was recovered and would not miss any team training or games. Individual testing was done both in the mornings and in the evenings. The testing took part from the end of November to the end of December 2016. Countermovement jumps (CMJ) purpose was to measure leg power of the futsal players, isometric leg press was to analyse the maximal leg strength of the futsal players, and the maximal treadmill running test to find out about the endurance capacity of the futsal players. The testing protocol was as follows:

- Filling of the pre-information, health-questionnaire and the written consent for the study
- Height and InBody measurements
- Compulsory 5 min jogging warmup on a treadmill follower by individual mobility/stretching
- CMJ test, 3 attempts with 1 min break in between
- Isometric leg press, 3 attempts with 1 min break in between
- Maximal treadmill running test
- Cooldown on a treadmill

The CMJ test was measured in both contact mat and force platform at the same time, to ensure precise results. Flight time was calculated from the both contact mat and the force platform, and later the jump height was calculated from the flight time. Few familiarisation jumps, serving also as a warmup, were done before the three attempts. The player kept his arms in contact with the waist during the whole jump, descended to half-squat and jumped as high as possible. In the isometric leg press three attempts were recorded after few familiarisation/warmup repetitions. The knee ankle was measured 110° for all players. The advice was to hold the handles, keep back in contact with the back support and push the leg support as hard as possible for few seconds, without plantarflexing the ankles. Verbal instructions and encouragement were given during the performance. The maximal force output was later analysed from each performance manually.

The maximal treadmill running test protocol was the same used by both Castagna et al. (2009) and Álvarez et al. (2009) for futsal players. After the warmup described before, the player ran 6 minutes at speed 8 km/h, and then velocity was increased by 1 km/h every minute until exhaustion, usually in 8-12 minutes (Castagna et al. 2009; Álvarez et al. 2009). The angle in the treadmill was 1° throughout the test (Castagna et al. 2009; Álvarez et al. 2009). The purpose was to find out the maximal oxygen uptake (VO2max) of the futsal players. VO2max was reached when at least two of the following criteria realized:

(1) a plateau in VO2 despite increasing treadmill speed
(2) a respiratory exchange ratio above 1.10

(3) HR reached ±10 bpm of predicted HRmax (220-age)

(4) the player ended the test voluntarily

(for 1-3 Castagna et al. 2009; Álvarez et al. 2009)

Before each test ambient, volume and gas analyser (using O2 and carbon dioxide) calibration were done. Heart rate (HR) was monitored continuously with a Polar Heart Rate monitor, and analysed with the Polar Flow-software. Running economy (RE) was measured as an average of VO2 and average of HR in the last minute of the 6-min run at 8 km/h (Castagna et al. 2009; Álvarez et al. 2009). Maximal speed was the velocity in the last stage of the test, if the player ran more than 5 seconds in that stage. VO2max and VEmax was considered as the highest 5 s mean during the treadmill test (Álvarez et al. 2009). HRmax was analysed as the highest HR achieved during the test from the Polar Flow-software. Average HR was analysed from the whole running test in Polar Flow-software.

Game measurements. Two official Finnish Futsal League games were studied from both teams totalling four games. The games were played according to the Finnish Futsal League schedule, and therefore overlap partly with the individual test times (figure 7). The games were played in the same court where both teams have their normal training, on a high-quality indoor parquet. The game measurements included HR monitoring and movement data through the game using Polar TeamPro-system, including Polar Pro-sensor (10 Hz GPS, 200 HZ motion sensor). Polar Pro-sensor has MEMS-movement sensor (accelerometer, gyroscope, digital compass), and it collected the following data:

- heart rate & heart rate variability
- maximal speed, velocities in different intensities
- total distance, distance in different intensities
- number of sprints
- accelerations & decelerations

Sprint threshold velocity was 19 km/h, which had to be exceeded momentarily. The distance of the sprint did not account. Maximal speed was also the momentary velocity achieved during the sprint. Speed zones were classified as:

- speed zone 1: 3-6.99 km/h
- speed zone 2: 7-10.99 km/h
- speed zone 3: 11-14.99 km/h
- speed zone 4: 15-18.99 km/h
- speed zone 5: > 19km/h

Accelerations and decelerations were both divided in to four categories by the change in velocity, according to the manufacturers guidelines. The categories were named as slow (0.50-0.99 m/s^2), medium (1.00-1.99 m/s^2), high (2.00-2.99 m/s^2) and maximal (3.00-50.00 m/s^2). Deceleration categories were divided the same way with a negative value.

All data was send in real time to iPad attached to the Polar Pro-Team docking station, and uploaded to the Polar TeamPro cloud computing. From the Polar TeamPro service, data was imported to Microsoft Excel and then further analysed. Data was split so that only the actual match-time was analysed. This included all activities from kick-off until full-time, excluding time-outs and the half-time (Dogramaci & Watsford 2006). Analyses were executed either comparing the halves, or for the whole game, depending on the situation. HR monitoring and movement data were collected in all four games.

CMJ and blood lactate were analysed in three points during the futsal games, but only in one game for each team totalling two games. The measurement points were after the warmup (15-5 min before the game), in the half-time (0-10 min after the first half) and after the game (5-15 min after the second half). The measurement order was random and depended on who player came first. CMJ and blood lactate measurements took in total about 10 minutes for the whole team. CMJ was measured on the contact mat, the same that was used in the individual tests. Flight time was recorded and later the jump height was calculated from the flight time. Player had three attempts with a short 10 s recovery between the attempts, and the best attempt was used in the analysis. Blood lactate was collected from the fingertip in a capillary and stored for later analysis. The analysis was done with Biosen C-line lactate analyser (EKF Diagnostic). Before the analysis, the lactate analyser was calibrated with the manufacturer guidelines, using a calibration solution of a known concentration.

In the game analyses match-time was used, which excluded the time-outs and the half-time (Dogramaci & Watsford 2006). Therefore, all actions were player is resting on the bench and not playing on the court is included. All player's playing time was counted from the video analysis. Each players time was counted every time he was on the court, and added up for the total playing time in the game. Both halves were investigated separately. To exclude the times when the game was not running, the sum of the playing time in each half was divided by the length of the half (excluding time-outs) and multiplied by 20. If the playing time was less than 6 minutes in either half, that half and the whole game results were excluded from the data.

8.3 Statistical analysis

All data is reported as mean ± standard deviation (SD). Significance was assumed at 5 % ($p \leq 0.05$). Results where $p < 0.10$ were mentioned separately. Statistical analyses were executed with the IBM SPSS Statistics Version 24. Data was imported to the SPSS program and then further analysed. Normality was tested with Shapiro-Wilks test. All data was normally distributed. Comparison between the two halves was done with paired-samples t-test. Comparison between data points during the futsal games was done with SPSS general linear model repeated measures procedure.

9 RESULTS

9.1 Physical performance tests

Physical performance tests strength and power measurement results are in table 8. Only on-field players were measured, goalkeepers were excluded. In the sprint and agility tests all players from the two team were involved, even though they did not participate in the other physical performance tests or in the game measurements. Therefore, the number (n = 22) is bigger than in the other results. 5-m sprint time was 1.03 (± 0.04 s) and 20-m sprint time 3.01 (± 0.07 s) (table 8). Agility test time was 6.87 (± 0.25 s) (table 8). CMJ height was almost 42 cm measured in both force platform and contact mat (table 8). In the CMJ results there was no difference when measured in force platform or contact mat ($p > 0.05$), showing good between-unit reliability. Isometric leg press showed quite large standard deviation in the results (table 8).

TABLE 8. Strength and power test results. All results are mean ± SD.

Strength and power tests	Result
5-m run (n = 22)	1.03 ± 0.04 s
20-m run (n = 22)	3.01 ± 0.07 s
Agility test (n = 22)	6.87 ± 0.25 s
CMJ force platform (n = 19)	41.9 ± 5.5 cm
CMJ contact mat (n = 19)	41.8 ± 5.6 cm
Isometric leg press (n = 19)	5327 ± 1070 N

Table 9 summarizes the endurance test results. One test result had to be removed due to questionability in reliability (n = 18). HRmax was 191.6 (± 9.5 bpm), VEmax 171.9 (± 20.8 l/min) and VO2max 59.8 (± 5.4 ml/kg/min) in the maximal treadmill running test (table 9). Average running time was 15min 53 s (± 1min 20s). Running economy (RE) as percentage was 70.8 (± 6.9 %) of HRmax and 55.7 (± 5.1 %) of VO2max. Peak speed achieved during the test was 18.4 (± 1.3 km/h).

TABLE 9. Results from the maximal treadmill running test. All results are mean ± SD. HRmax = maximal heart rate in the running test. HRaverage = average HR during the whole running test. RE HR = Running economy as heart rate during the 5:00-6:00 of the running test. RE HR of HRmax = Percentage of running economy heart rate from the maximal heart rate. VEmax = maximal ventilation in the running test. VO2max = maximal oxygen uptake in the running test. RE VO2 = Running economy as oxygen uptake during the 5:00-6:00 of the running test. RE VO2 of VO2max = Percentage of running economy oxygen uptake from the maximal oxygen uptake.

Maximal treadmill running test (n = 18)	Result
Running time (min:s)	15:53 ± 1:20
HRmax (bpm)	191.6 ± 9.5
HRaverage (bpm)	153.4 ± 12.1
Peak speed (km/h)	18.4 ± 1.3
RE HR (bpm)	135.8 ± 16.2
RE HR of HRmax (%)	70.8 ± 6.9
VEmax (l/min)	171.9 ± 20.8
VO2max (ml/kg/min)	59.8 ± 5.4
RE VO2 (ml/kg/min)	33.2 ± 2.6
RE VO2 of VO2max (%)	55.7 ± 5.1

9.2 Game measurements

Distance. The total distance covered during the futsal games ranged on average between 3913-4835 m (figure 8). The average distance covered in all the games was 4463.0 (± 1169.3 m). There was no statistical difference in the distance covered between the four games ($p > 0.05$). Average distance covered was 2237.8 (± 511.7 m) in the first half, and 2136.3 (± 741.9 m) in the second half. Only in game 4, there was a reduction in the distance covered from the first half to the second half, from 2434 m to 1987 m ($p = 0.036$) (figure 8). Standard deviations in the total distance covered were larger in the first two games (over ± 1200 m), compared to the last two games (less than ± 900 m) (figure 8).

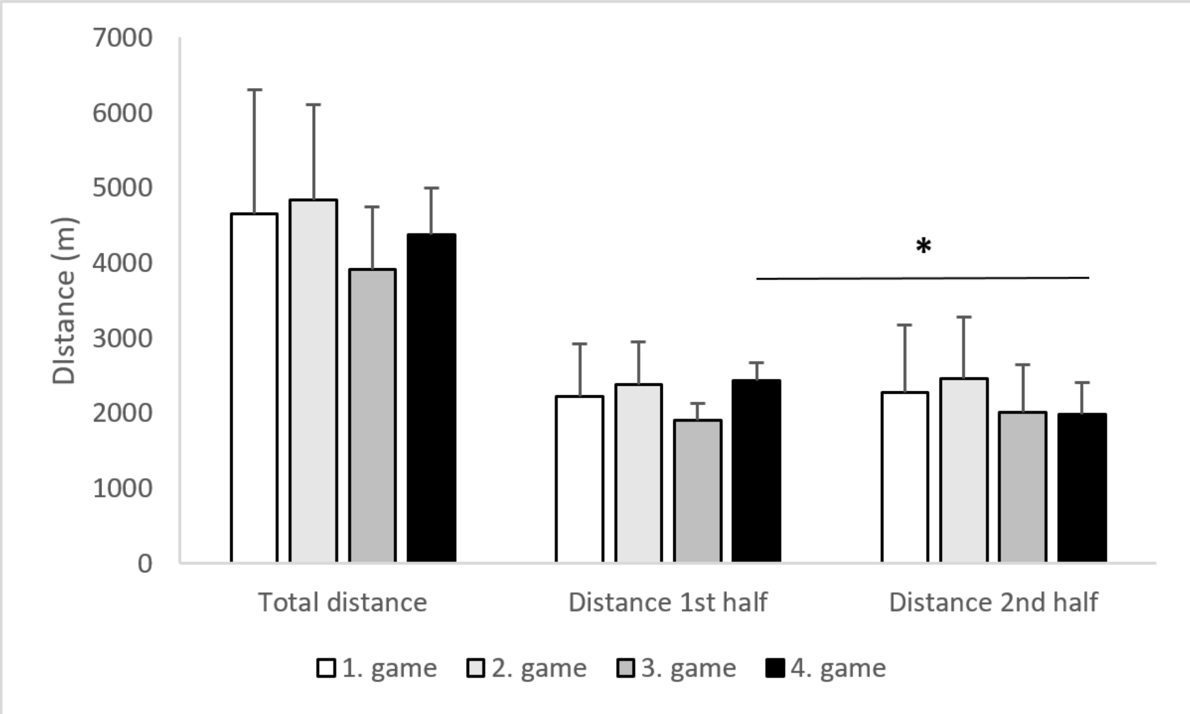


FIGURE 8. Running distance measured in 4 four futsal games. Results are mean ± SD. * $p < 0.05$.

Playing time. Average playing time in the four futsal games was 9:54 (± 1:52 min:s) in the first half (n = 24), 10:09 (± 2:34 min:s) in the second half (n = 22), and 20:42 (± 4:07 min:s) in the whole game (n = 19). There was no difference in playing time between the two halves ($p > 0.05$). The highest playing time for one player was 14:58 min:s in one half, and 27:39 min:s in one game.

Heart rate. Figure 9 shows the maximal and average heart rates during the futsal games, and the average HR from the both halves measured in all four futsal games. There was no statistical difference between the games in any HR measurement, as seen in figure 9 ($p > 0.05$). There were also no differences between the two teams in any HR variable. In the four futsal games, the HRmax was 191.6 (± 9.9 bpm) and the average HR 147.0 (± 16.9 bpm), ranking 76.7 % of the HRmax. Average HRs were 147.3 (± 15.6 bpm) and 145.2 (± 19.5 bpm) in the first and second half, respectively, having no statistical difference between the halves ($p > 0.05$). The maximal HR achieved during the games was the same as achieved in the maximal treadmill running test (191.6 vs 191.6 bpm, respectively).

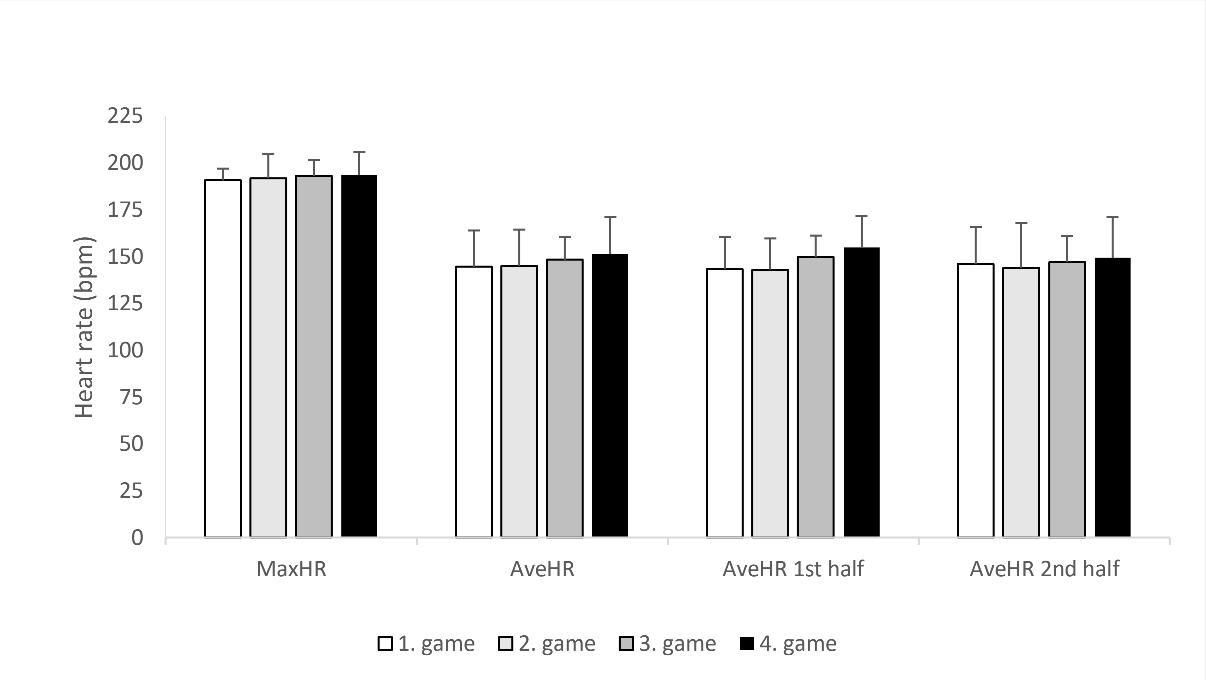


FIGURE 9. Heart rates during the futsal games. Results are mean ± SD.

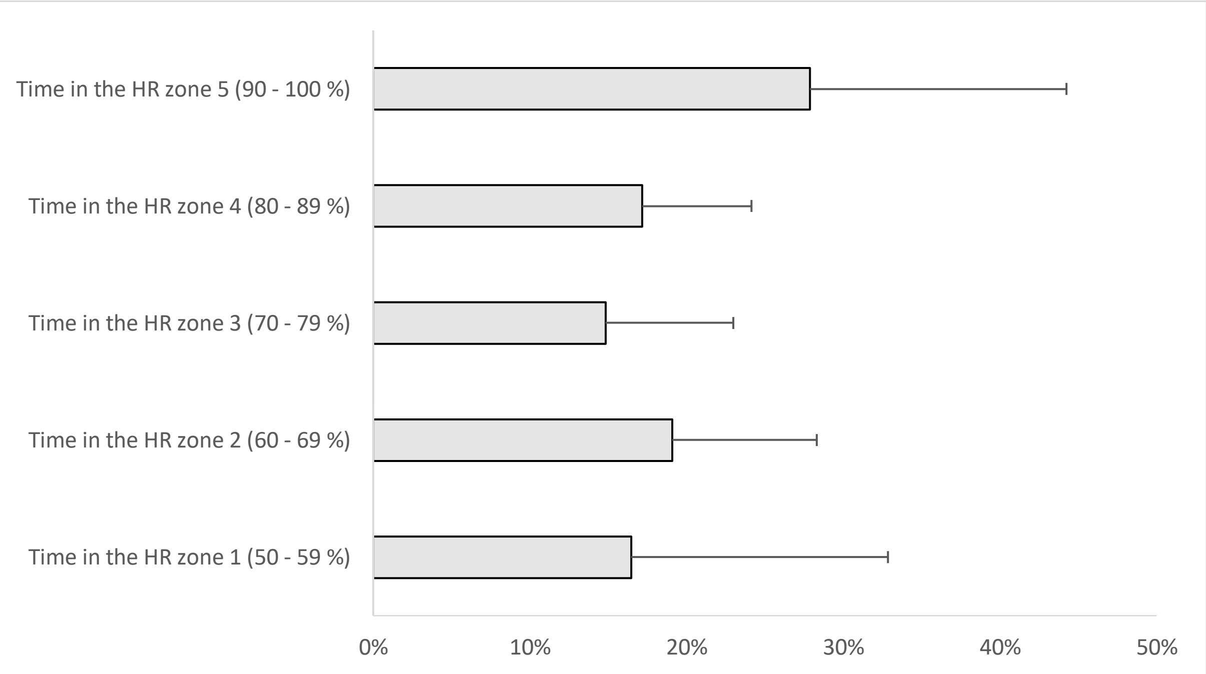


FIGURE 10. Time spend in different HR zones during the futsal games. Results are mean percentage ± SD.

HR in different zones during the futsal games is presented in figure 10 (n = 24). 27.9 % of the game HR was between 90-100 % of HRmax, and 17.2 % of the game between 80-89 % of HRmax. In total, almost half of the time (45.1 %) HR was over 80 % of the players maximal

HR (figure 10). Only 35.6 % of time HR was between 50-69 % of HRmax (HR zones 1 and 2), or under 50 % of the HR max (4.6 %). Time in the HR zone 1 likely decreased from the first half to the second half ($p = 0.085$). Other changes were not noted between the halves in other HR zones. HR analyses included all match-time activities.

Intensity & sprints. The average intensity in the futsal games was 54.0 (± 13.2 m/min) (n = 24). No differences in the intensity between the games were observed ($p > 0.05$). In one game, there was a likely decrease in the intensity from the first half to the second half ($p = 0.078$) (figure 11). On average, intensity was 54.0 (± 11.3 m/min) in the first and 52.7 (± 16.9 m/min) in the second half (figure 11).

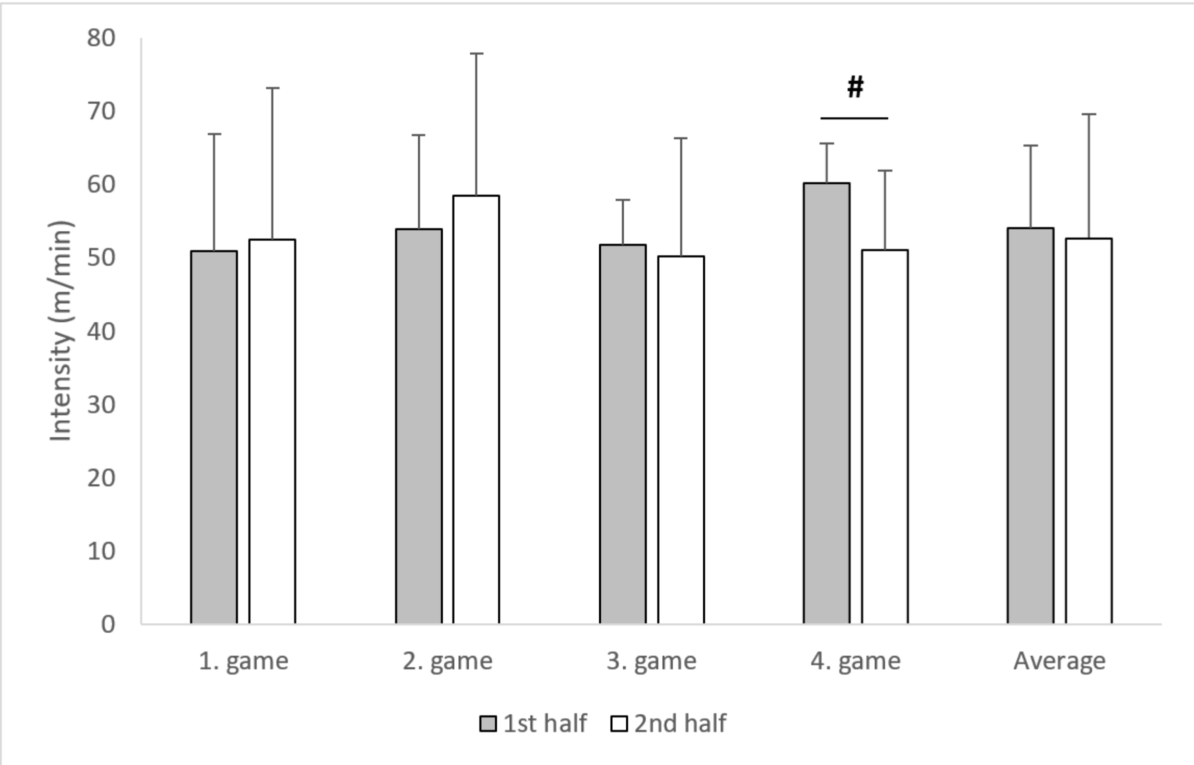


FIGURE 11. Intensity measured in four futsal games first and second half and the average of all games. Results are mean ± SD. # $p < 0.10$.

Number of sprints in the futsal games is shown in figure 12. The average number of sprints in all games was 39.7 (± 17.2). Large standard deviation was noted in all games. There was a difference in the number of sprints between the halves in the game 3 ($p = 0.014$), and likely difference in the games 2 ($p = 0.078$) and 4 ($p = 0.064$). No differences in the number of sprints between the games were noticed (figure 12). The maximal speed achieved in the games was on average 27.5 ± 1.4 km/h (7.6 ± 0.4 m/s).

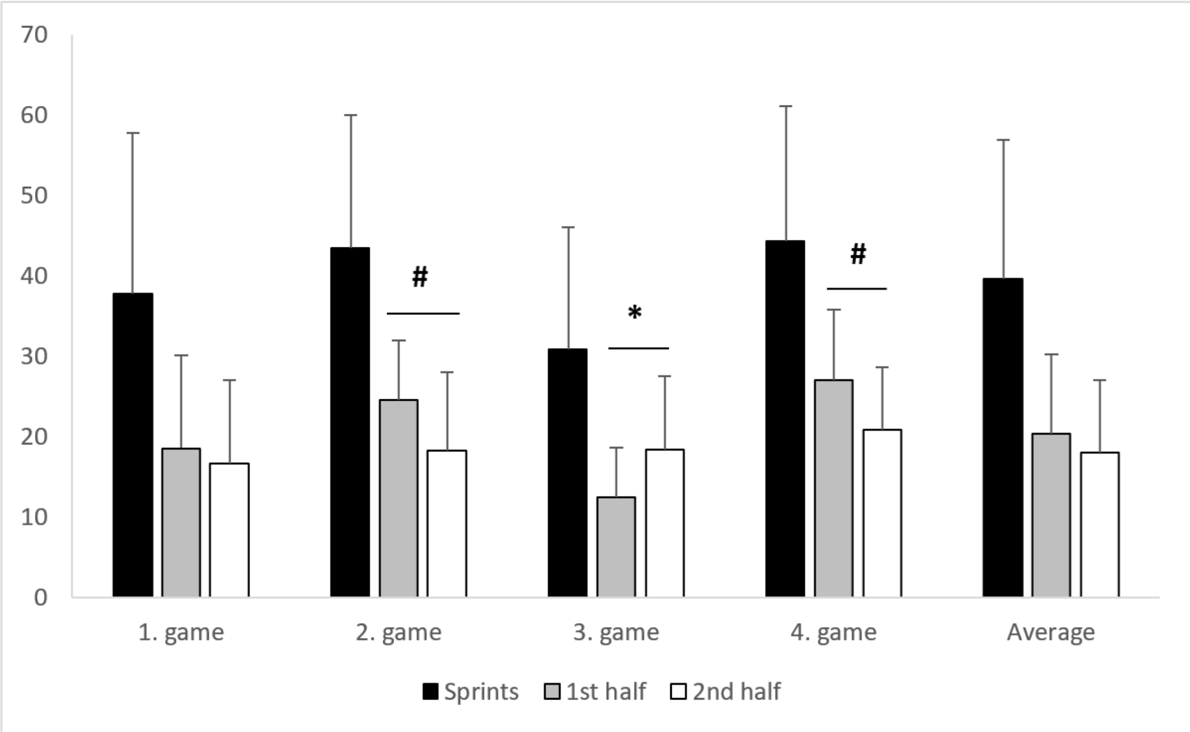


FIGURE 12. Sprints during the futsal games. Results are mean ± SD. * $p < 0.05$. # $p < 0.10$.

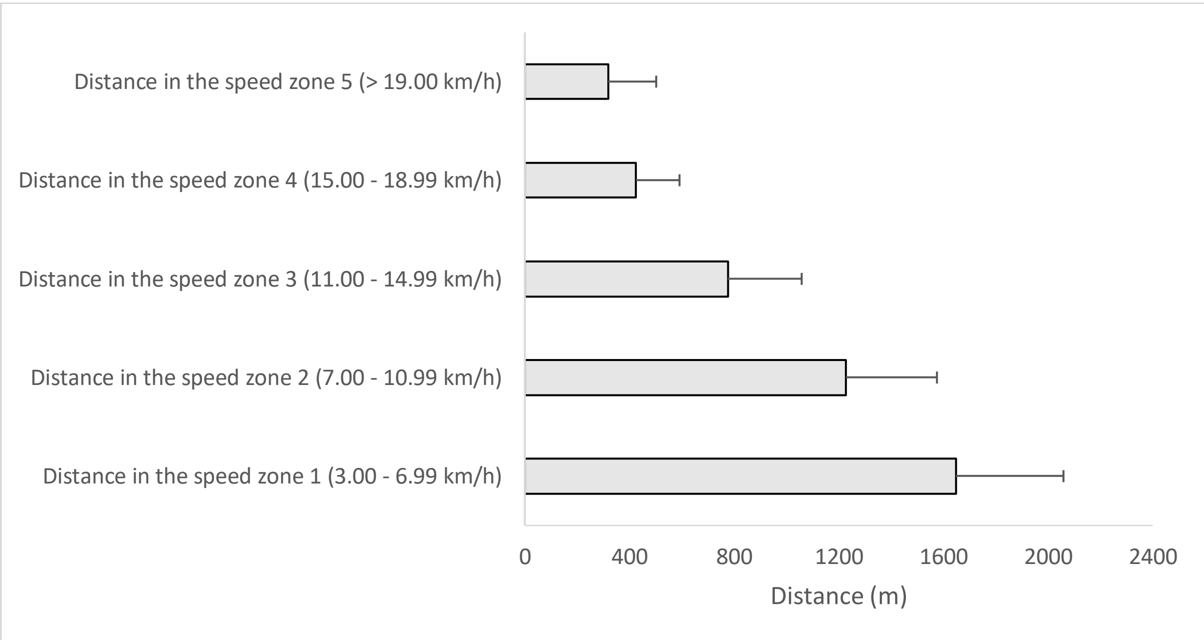


FIGURE 13. Mean ± SD distances in different speed zones during the four futsal games.

Relative distances moved in different speed zones in the futsal games are in figure 13 (n = 24). Almost two third of the distance (65.4 %) was covered in lower intensity speed zones 1 and 2 (1648 ± 411 m and 1228 ± 348 m, respectively). Only 7.2 % and 9.7 % of distance was moved in high intensity speed zones 5 and 4 (319 ± 184 m and 425 ± 166 m, respectively), totalling 16.9 % of distance (figure 13). There were no differences between the halves in any speed zones measured ($p > 0.05$).

Acceleration & deceleration. Data from all four games accelerations and decelerations are presented in figure 14, table 10, and in appendix 3. Classification of accelerations and decelerations is in chapter 8.2. Comparison of accelerations and decelerations is presented in figure 14 where differences were noted mostly between games 1 and 3, and game 2 and 3 (figure 14).

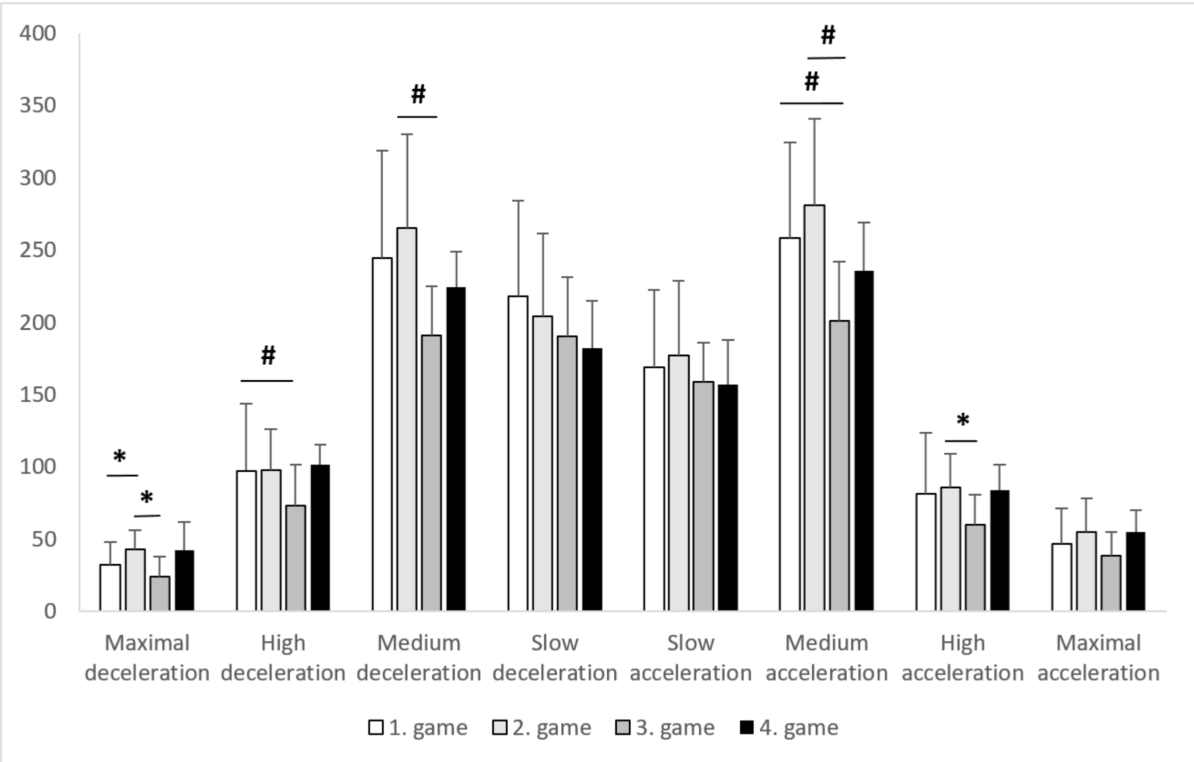


FIGURE 14. Accelerations and decelerations in four futsal games. Results are mean ± SD. * $p < 0.05$. # $p < 0.10$.

Between the halves, statistical differences were noted in game 1 medium deceleration (114.1 ± 32.3 vs 125.1 ± 37.1*), medium acceleration (118.3 ± 26.2 vs 133.3 ± 37.1*), in game 2 maximal deceleration (24.0 ± 5.9 vs 17.1 ± 8.3#), in game 3 maximal acceleration (17.3 ± 8.1

vs 21.0 ± 8.2*) and in game 4 maximal deceleration (24.7 ± 10.0 vs 18.8 ± 8.5*) (table 10). The same data is presented in appendix 3 as a figure.

TABLE 10. Accelerations and decelerations in the futsal games. Results are mean ± SD. Games are divided by number and then further to two halves. * = p < 0.05. # = p < 0.10.

		Deceleration (range)				Acceleration (range)			
Game number	Half	Maximal (-50.00 - -3.00 m/s^2)	High (-2.99 - -2.00 m/s^2)	Medium (-1.99 - -1.00 m/s^2)	Slow (-0.99 - -0.50 m/s^2)	Slow (0.50 - 0.99 m/s^2)	Medium (1.00 - 1.99 m/s^2)	High (2.00 - 2.99 m/s^2)	Maximal (3.00 - 50.00 m/s^2)
1	1 (n = 7)	15.0 ± 8.3	46.0 ± 22.8	114.1 ± 32.3	103.0 ± 25.8	82.3 ± 24.1	118.3 ± 26.2	36.6 ± 21.8	23.1 ± 14.5
	2 (n = 7)	15.7 ± 8.2	46.7 ± 23.8	125.1 ± 37.1*	108.3 ± 37.4	81.7 ± 27.8	133.3 ± 37.1*	39.7 ± 20.5	22.1 ± 11.4
2	1 (n = 7)	24.0 ± 5.9	45.4 ± 15.5	128.7 ± 24.4	93.7 ± 28.4	84.3 ± 23.9	134.3 ± 21.7	39.0 ± 12.1	29.7 ± 10.5
	2 (n = 9)	17.1 ± 8.3#	49.8 ± 18.9	121.6 ± 50.1	96.9 ± 40.1	81.9 ± 33.6	129.8 ± 52.7	42.7 ± 15.9	23.3 ± 13.2
3	1 (n = 6)	11.0 ± 6.9	35.2 ± 13.9	94.0 ± 12.4	95.5 ± 22.9	79.8 ± 13.0	100.8 ± 20.8	28.7 ± 7.9	17.3 ± 8.1
	2 (n = 6)	13.2 ± 7.3	38.0 ± 15.2	96.8 ± 24.1	95.0 ± 24.9	78.8 ± 15.1	100.3 ± 22.4	31.0 ± 16.3	21.0 ± 8.2*
4	1 (n = 6)	24.7 ± 10.0	57.0 ± 11.3	113.5 ± 10.3	90.5 ± 13.3	78.0 ± 14.9	122.7 ± 9.3	47.8 ± 11.7	29.3 ± 5.2
	2 (n = 5)	18.8 ± 8.5*	45.2 ± 5.0	107.0 ± 20.7	88.2 ± 26.2	75.6 ± 20.5	110.6 ± 27.9	37.2 ± 6.7	25.4 ± 9.6
Average	1 (n = 25)	18.7 ± 9.4	45.9 ± 17.4	113.3 ± 24.5	95.9 ± 22.7	81.3 ± 19.0	119.6 ± 23.0	38.0 ± 15.3	25.0 ± 11.0
	2 (n = 27)	16.2 ± 7.8	45.5 ± 17.6	114.3 ± 37.4	97.8 ± 33.1	80.0 ± 25.3	120.6 ± 39.7	38.3 ± 15.9	22.9 ± 10.6

9.3 Fatigue during the futsal games

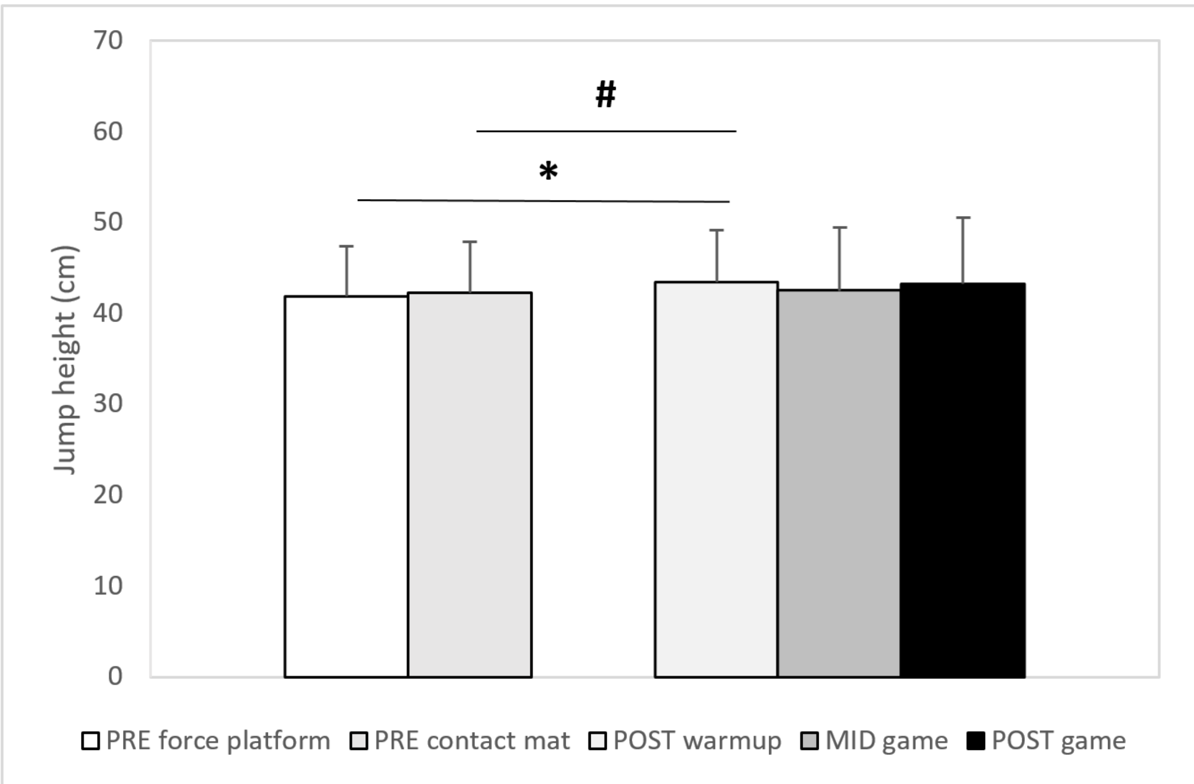


FIGURE 15. Countermovement jump results from the individual tests compared to the game measurements post warmup, mid game and post game. Results are mean ± SD. * p < 0.05. # < 0.10.

Countermovement jump. CMJ jump height results are in figure 15. There was no difference between the CMJ jump height during the game (post warmup, mid game, post game, $p > 0.05$). The average jumping height was 43.5 (± 5.7 cm) post warmup, 42.5 (± 6.9 cm) mid game and 43.2 (±7.3 cm) post game. However, CMJ jump height increased from the reference value to post warmup when measured with the force platform ($p = 0.040$), and likely when measured with the contact mat ($p = 0.080$) (figure 15).

Lactate. Post warmup lactate was 3.62 (± 3.59 mmol/l), in the mid game 5.54 (± 3.16 mmol/l) and post game 4.47 (± 2.97 mmol/l). The average lactate during the futsal games in all measurements was 4.53 (± 3.22 mmol/l). Only on-field players lactate values were measured ($n = 20$). There were no statistical differences in any lactate measurement point during the game (post warmup, mid game, post game, $p > 0.05$).

Players fitness level. Players fitness level measured in individual tests had no effect on the fatigue during the game. Any individual test variable (VO2max, CMJ or isometric leg press) had no correlation to the amount of fatigue during the game, measured as CMJ ($p > 0.05$) or as lactate ($p > 0.05$).

10 DISCUSSION

The purpose of this study was to find out the physical performance profile of Finnish futsal players, and to find out whether Finnish Futsal League games result in acute physical fatigue. Research questions were: does the game intensity drop between the first and the second half of the game, does the speed and strength qualities decrease during or after the futsal game, and what is the physical performance of Finnish futsal players.

The main results from this study were that Finnish futsal player's physical performance is comparable to international level when compared to the results from futsal literature, and that Finnish Futsal League games caused no acute fatigue measured in CMJ jump height or blood lactate.

10.1 Physical performance tests

The sprinting times in this study are similar when compared to Spanish, Brazilian and New Zealand futsal player results in table 5 (Gorostiaga et al. 2009; Nakamura et al. 2016; Naser & Ali 2016). 5-m sprinting times of 1.00 s and 20-m sprinting times of 3.00 s seems to be quite average results for futsal players (table 5). Finnish players results 1.03 s in 5-m sprint and 3.01 s in 20-m sprint are comparable to international level. Measuring sprinting over distances of 30-m seems irrelevant in futsal since the average sprinting distance ranges between 10-14 m (Castagna et al. 2009; Caetano et al. 2015). Therefore, it can be speculated whether maximal speed is achieved during the futsal games, and if it has any meaning for the performance. Maximal speed achieved during the futsal games was 27.6 (± 1.4 km/h), but whether this was the absolute maximal speed of the players were not measured.

The agility test used in this study is not previously used in futsal studies. The same test is used in football in Sami Hyypiä Academy and in Finnish Floorball Federation. The only exception is that in Sami Hyypiä Academy, the last stick is touched, and in Finnish Floorball Federations test the last stick is replaced with a goal that is touched. In this study, the last stick was circled (appendix 2), which adds the total time in the test. Several agility tests would have been needed to see changes in the player's ability to change direction during the futsal season.

The CMJ results of around 42 cm measured on pre-tests are good results for futsal players when compared to literature. Results between 38-40 cm have been reported in many studies (Gorostiaga et al. 2009; Nakamura et al. 2016). CMJ results are always biased by the methodological differences, and the instructions for the jumping performance, and therefore comparing different results directly is not possible. However, it seems that Finnish futsal players leg power measured in CMJ height are in a good level.

Isometric leg press results are not comparative because of the specificity of different leg presses available. The leg press results measured in this study showed a large SD (range 3332-6969 N, mean 5327 N), which was probably partly result of different training background and hence in ability to produce maximal all-out effort in the isometric situation. Isometric testing is highly joint angle specific (Bompa & Haff 2009), and better option would have been half- or full squat to test maximal leg strength. However, squat testing would have required a lot of training which was not possible in this study, and that is why isometric leg press was used for testing the maximal leg strength of futsal players.

The results from the maximal treadmill running test are in table 9. All the results (peak treadmill speed, running economy, VEmax and HRmax) were in line with those in literature (Castagna et al. 2009; Álvarez et al. 2009). VO2max result was a little lower (table 9), but the players measured in other studies were professional players from Spain (Castagna et al. 2009; Álvarez et al. 2009), when the players in the current study can be considered semi-professionals at most. Futsal players need a well-developed aerobic power, measured as VO2max, to be able to cope with the high-intensity actions during the gameplay (Castagna et al. 2009). In this study, the Finnish on-field futsal players VO2max was 59.8 (± 5.4 ml/kg/min) measured during the competitive season. This value can be considered as sufficient to be able to play futsal in high-intensity and in high level.

10.2 Game measurements

Official games have been used before in futsal studies (Charlot et al. 2016; Caetano et al. 2015; De Oliveira Bueno et al. 2014; Rodrigues et al. 2011; Barbero-Alvarez et al. 2008). Measuring and studying in official games has many advantages, and translates well to practice. The weakness is that not all aspects of the games can be controlled or measured. For example, the half-time is fixed and limits measuring between the two halves. With the known limitations, measuring in official games was chosen in this study.

Futsal players ran on average 4463.0 (± 1169.3 m) on the games and there were no differences in the distance between the four games. Distances in this study were both lower and higher compared to other studies (table 3). It can be concluded that the distance covered in this study is comparable to distances measured in other futsal studies, where the distance covered ranges between 3000-6000 m during the game. Large SDs in the results are probably partly explained by the differences in playing time. Differences in the distance covered in the literature (table 3) is due to different measuring techniques (clock-time vs match-time) and different playing level.

The heart rate and speed zones used in this study differ from the literature. In this study, players spend 45.1 % of time in HR over 80 % of HRmax, whereas the number was 83 % of time in HR over 85 % of HRmax in Barbero-Alvarez et al. (2008), and 52 % of time in HR over 90 % of HRmax in Castagna et al. (2009). Results from this study are closer to those reported by Castagna et al. (2009), though somewhat lower. Barbero-Alvarez et al. (2008) used clock-time analysis, where all the breaks in the game are excluded from the data, and therefore clock-time analysis increases the amount of high-intensity actions including higher HR values (Dogramaci & Watsford 2006). Therefore, average HR during the games was also lower in this study 147.0 (± 16.9 bpm), compared to 174 (± 7 bpm) in Barbero-Alvarez et al. (2008). However, HR values were high when almost half of the game HR was over 80 % of HRmax, including the time when the player was resting on the bench. High HR values are results from a heavy stress to the anaerobic metabolism, which is result from repeated high-intensity actions during the games.

The average intensity during the futsal games was 54.0 (± 13.2 m/min) which is lower compared other studies (De Oliveira Bueno et al. 2014; Dogramaci et al. 2011; Castagna et al. 2009; Barbero-Alvarez et al. 2008). Part of the differences are probably explained by the different analysis methods. Previously mentioned studies analyses are done from the clock-time analysis. Furthermore, De Oliveira Bueno et al. (2014) reported intensity in whole match, out of play and in play situations from the same futsal game. The values were 94.1 (± 14.1 m/min), 57.8 (± 12.6 m/min) and 132.9 (± 17.0 m/min), which shows the large differences depending on the analyse method used (De Oliveira Bueno et al. 2014). However, the game intensity in this study is lower to values in literature, which points out that speed of the play is lower, even though the total distance covered is almost equal. This is further supported by the previous analysis of lower average HR and less time in the high HR zones compared to other studies (Barbero-Alvarez et al. 2008; Castagna et al. 2009).

There was on average 39.7 (± 17.4) sprints in the futsal games, which is more than in Brazil's Futsal League and in 4 x 10 min period of simulated futsal game (Caetano et al. 2015; Castagna et al. 2009). This is a bit surprising since the overall game intensity (m/min) in this study was lower, yet the highest intensity actions (sprints) happened more often. The results should be compared with caution, because the analysis methods and sprint thresholds are different. In two games the number of sprints likely decreased to second half (figure 12, $p < 0.10$), but in one game increased ($p < 0.05$). Caetano et al. (2015) found no changes in any sprint variables between the two halves, except sprinting duration increased a little. They suggest that physical performance was maintained through the game because of the unlimited amount of substitutions allowing to avoid fatigue (Caetano et al. 2015). The same can be stated here since the decrease in the two games sprints was not statistically strong ($p < 0.10$).

Comparison of speed zones is difficult because of different velocities, but the percent distance travelled in each speed zones can be compared with caution. It seems that the two highest intensity categories speed zones range from 12.0-21.1 % of total distance in literature (Barbero-Alvarez et al. 2008; Castagna et al. 2009, De Oliveira Bueno et al. 2014). Biggest differences seem to be in the lowest categories, where in this study more time is spent on the lowest category (Zone 1, figure 13), compared to literature (Barbero-Alvarez et al. 2008; Castagna et al. 2009, De Oliveira Bueno et al. 2014). These differences in distances in high- and low-intensity speed categories may explain the differences in overall intensity (m/min) which was noted to be lower in this study compared to the other futsal studies.

Accelerations and decelerations are presented in figure 14, table 10 and appendix 3. There were few changes between the different variables between the games (figure 14), and between the first and the second half (table 10), but mostly both accelerations and decelerations in different categories remained levelled through the games. Futsal games included on average 48.6 (± 20.4) and 35.3 (± 16.4) maximal accelerations and decelerations, respectively. There is no comparison data, but the number of both accelerations and decelerations seems to be high during the futsal games. Whether these actions included a change of direction was not measured, but it can be speculated that regarding the nature of futsal, often when accelerating or decelerating velocity, it is accompanied by change of direction.

10.3 Fatigue

In this study fatigue was examined acutely during and after the futsal games measured in CMJ jump height and blood lactate. Blood lactate is used to study the involvement of anaerobic metabolism during team sports (Makaje et al. 2012). The average lactate measured in two futsal games was 4.53 (± 3.22 mmol/l). This is close to values between 5.0-5.5 mmol/l measured in previous studies in random blood sampling. (Castagna et al. 2009; Makaje et al. 2012). In this study, blood lactate was measured in three points: before the game after the warmup, in the half-time, and after the game. The limitation in blood lactate measurement is that it is not a straight results of muscle lactate value, because the removal of blood lactate is slower than that of muscle lactate (Makaje et al. 2012). Considering the high SD in the blood lactate results, it can be argued that some players reached blood lactate values close or over 10 mmol/l at some point of the futsal games, which means heavy involvement of anaerobic metabolism.

The CMJ results did not change during the game in any three points measured. The only changes were noted from the individual tests CMJ jump heights, used as a reference value, compared to the post warmup jump height before the futsal game (figure 15). The jump height increased which can be explained by longer warmup. In the individual tests the warmup included a 5-min treadmill running and light mobility/stretching, whereas the game warmup consisted of 25-30 min more complete warmup including high-intensity actions and small-sided games. The same was noted by Kainulainen (2015) in official floorball games, where the CMJ increased significantly from before warmup to after the first period.

In futsal, the amount of substitutions is unlimited, and therefore fatigue can be prolonged by changing the players more often (Dogramaci et al. 2015). In this study, the average playing times in each half ranged between 49-51 % of total time with relatively small SD. This indicated that in Finnish Futsal League, the playing time on and off the court divided very closely to the ratio of 1:1. This means that half of the time player is on the court and half of the time resting on the bench. Therefore, players have enough time to recover during the time off the court, which may explain that no differences were noted in the measured values (lactate, CMJ) of fatigue during or after the game. It can also mean that aerobic fitness of players in this study was good enough that they recover during the times off the court. This is supported by the high values of VO2max.

Barbero-Alvarez et al. (2008) found a decrease in the average HR between the halves. In this study, no decrease in average HR between the two halves was noted (147.3 bpm and 145.2 bpm, $p > 0.05$). Likewise, Castagna et al. (2009) found no differences in average HR during game periods of 4 x 10 min simulated futsal game. Decrease in HR means decrease in the intensity, which was not noted here. This can be due to even distribution of playing time in this study, where players had enough time to rest when they were not on the court. During the time on the court they were able to keep the intensity for the duration of the whole game. Decrease in the total distance in one game (figure 8) was accompanied with a simultaneous likely decrease in the game intensity (figure 11). Also, the number of sprints likely decreased (figure 12). Therefore, it can be concluded that in this game number 4, fatigue was evident based on decreases in total distance, intensity and sprints.

Fatigue was assessed only acutely during and after the futsal games, but not in long term. There are no studies of acute fatigue after futsal games, but few studies of accumulated fatigue from several futsal games played over a short period of time (Charlot et al. 2016; Freitas et al. 2014). In previously mentioned studies, authors found no or small decreases in performance (Charlot et al. 2016), or large decreases in performance (Freitas et al. 2014). In conclusion, it seems that performance will not decrease acutely after one futsal game, but when several games are played close to each other, the performance is more or less affected. Futsal games may be played on consecutive days during international tournaments, cup games or playoffs.

10.4 Strength and limitations

Heart rate (HR) monitoring and blood lactate are valid tools to measure performance, when their limitations are noticed (Barbero-Alvarez et al. 2008; Castagna et al. 2009; Makaje et al. 2012). HR is easier to interpret when it is expressed as percentage of HRmax, and divided to intensity classifications. In this research HRmax was measured in maximal treadmill running test ± two weeks of the game measurements, and can therefore be considered very reliable.

The physical performance of the futsal players was measured in one point of the season, in the middle of the competitive season. This gives a good result of the performance capabilities at that time, but discounts the performance during other times. Kainulainen (2015) found changes in the 20-m sprint test, CMJ, isometric strength tests and 5-jump test during the whole floorball season. In futsal players, the YoYo IR1 and best and mean RSA (repeated sprint ability) results stayed the same, but the fatigue in RSA increased from beginning of the season to the middle of the season (Oliveira et al. 2013). Measurements could have been done in different points of the season to assess changes in the physical performance. Thus, long term changes in performance could have been observed. However, these results represent Finnish futsal players in-season performance reliably, and can be compared to literature.

Possible sources of error are the measurement situation and data analysis. Some of the physical performance tests were new to the players, and learning may have happened during the testing session. Because all the measurements were done in one point of the season, the physical fitness at that current time affect the results. Player may have been injured before the testing, and not in full condition during the physical tests. Polar TeamPro-system is not yet validated and may have affected the measurement of HR, distance and velocity in the game measurements.

In this study ventilatory threshold (VT) was not defined unlike in many other futsal studies (Castagna et al. 2009; Álvarez et al. 2009; Pedro et al. 2013). Futsal players VT values have been between 67.5-71.5 % of VO2max values (Castagna et al. 2009; Álvarez et al. 2009; Pedro et al. 2013). Running speed at VT seems to discriminate playing level in futsal (Pedro et al. 2013). Higher level futsal players could run faster before reaching the VT (Pedro et al. 2013). Therefore, VT may be a better indicator of the playing level than VO2max, or at least they should be both included when measuring the physical fitness of futsal players.

In the literature, most fatigue research is conducted over a longer period after the game (Charlot et al. 2016; Rodrigues et al. 2011; Freitas et al. 2014). Therefore, it can be argued that this should have been included in this study. Also, more acute fatigue measurements could have been performed, but time was the limiting factor. Currently it took approximately 10 min to measure the whole team, which was the maximal time available in the official futsal game half-time. As Kainulainen (2015) suggests, blood lactate should be measured immediately when the player has played his or her last minutes in that half. Otherwise the resting time can be up to 15 min before the measurement. This would have given more time to measure other factors during the half-time. Also, post game lactate measurement could have included 5, 15 and 30 min after the game (Kainulainen 2015).

10.5 Conclusions & practical applications

The first hypothesis was that intensity would drop because of the neuromuscular fatigue. The hypothesis was untrue, because the game intensity (m/min) was only likely decreased in one measured game, and there were no large changes in sprinting variables, moved distances or heart rates. The second hypothesis was that player's capacity to produce force may decrease during the futsal game, or after the game during recovery. There was no changing in force producing capacity during or after the game, when measured as CMJ or blood lactate levels. The third hypothesis was that what is the physical performance of a Finnish Futsal League player. Based on the physical performance tests and the game measurements, Finnish player's physical fitness is comparable to international level.

The conclusion from the results is that Finnish futsal player's physical fitness is comparable to elite and professional futsal players results. Also, during Finnish Futsal League games the distance moved is similar to those measured in literature, but the game intensity lower when expressed in % of HRmax, moved distance per minute or in different speed zones. Statistical differences in ways of measuring may explain some of these differences, and should be carefully considered in future studies when selecting variables. Because fatigue was not evident during the games, higher-intensity tactic or less substitutions to the key players could be used during the games, at least when the recovery time before the next game is long.

Measuring in many points during the competitive season is recommended to examine changes in physical performance. More dynamic strength tests could be used, because the strength training in futsal is dynamic in nature, and maximal strength testing could also help to plan strength training. Sprint and agility tests were beneficial and relative to futsal. Sprinting could include 10-m split time but distances over 20-m are irrelevant in futsal. The agility test is highly important because futsal player move a lot in different direction (Dogramaci et al. 2011). Agility test should be chosen so that the results can be compared to others, or done many times to see the change in results. In the maximal treadmill running test, VT should be included in the analysis.

This study has only looked physical performance in futsal. Physical performance is centre of attention, because it is easiest to measure and evaluate. However, physical abilities are only one quality that futsal player needs. Additionally, futsal player need both tactical and technical skills, psychological skills to cope with success and failure, and enough sleep and quality food to recover from training and playing. In team sport, the individual player should be taken into account when planning and implementing physical training, since all players come from different backgrounds (Kainulainen 2015). The purpose in this study was to analyse top level male Finnish players, and therefore the results are not applicable to youth or female teams.

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12 APPENDICES

12.1 Appendix 1 - Pre-information and health-questionnaire

ESITIETO- JA TERVEYSKYSELY

Nimi: ______________________ Syntymäaika: __________ Paino: ______ kg Pituus: _____ cm

Testauksen turvallisuuden kartoittamiseksi pyydämme sinua täyttämään oheisen terveyskyselyn. Tämä on vapaaehtoinen kysely, mutta ellemme tiedä testaamisen olevan turvallista, emme voi sitä tehdä.

Oireet viimeisen 6 kk aikana:	Kyllä	Ei	En osaa sanoa
1. Onko sinulla ollut rintakipuja?			
2. Onko sinulla ollut rasitukseen liittyvää hengenahdistusta?			
3. Onko sinulla ollut huimausoireita?			
4. Onko sinulla ollut rytmihäiriötuntemuksia?			
5. Onko sinulla ollut harjoittelua estäviä kipuja liikuntaelimissä?			
Missä?			
6. Oletko tuntenut ylikuormitus- tai stressioireita?			

Todetut sairaudet: Onko sinulla tai onko sinulla ollut jokin/joitakin seuraavista? (ympyröi)

01 sepelvaltimotauti	02 sydäninfarkti	03 kohonnut verenpaine	04 sydänläppävika
05 aivohalvaus	06 aivoverenkierron häiriö	07 sydämen rytmihäiriö	08 sydämentahdistin
09 sydänlihassairaus	10 syvä laskimotukos	11 muu verisuonisairaus	12 krooninen bronkiitti
13 keuhkolaajentuma	14 astma	15 muu keuhkosairaus	16 allergia
17 kilpirauhasen toimintahäiriö	18 diabetes	19 anemia	20 korkea veren kolesteroli
21 nivelreuma	22 nivelrikko, -kuluma	23 krooninen selkäsairaus	24 mahahaava
25 pallea-, nivus- tai napatyrä	26 ruokatorven tulehdus	27 kasvain tai syöpä	28 leikkaus äskettäin
29 mielenterveyden ongelma	30 tapaturma äskettäin	31 matala veren K tai Mg	32 kohonnut silmänpaine
33 näön tai kuulon heikkous	34 urheiluvamma		

äskettäin

muita sairauksia tai oireita, mitä: ____

Lääkitys: Käytätkö jotain lääkitystä tai lääkeainetta säännöllisesti tai usein? 1 En 2 Kyllä, mitä:
____
____

Kuumetta, flunssaista oloa tai muuten poikkeavaa väsymystä viimeisen viikon aikana:
1 Ei 2 Kyllä

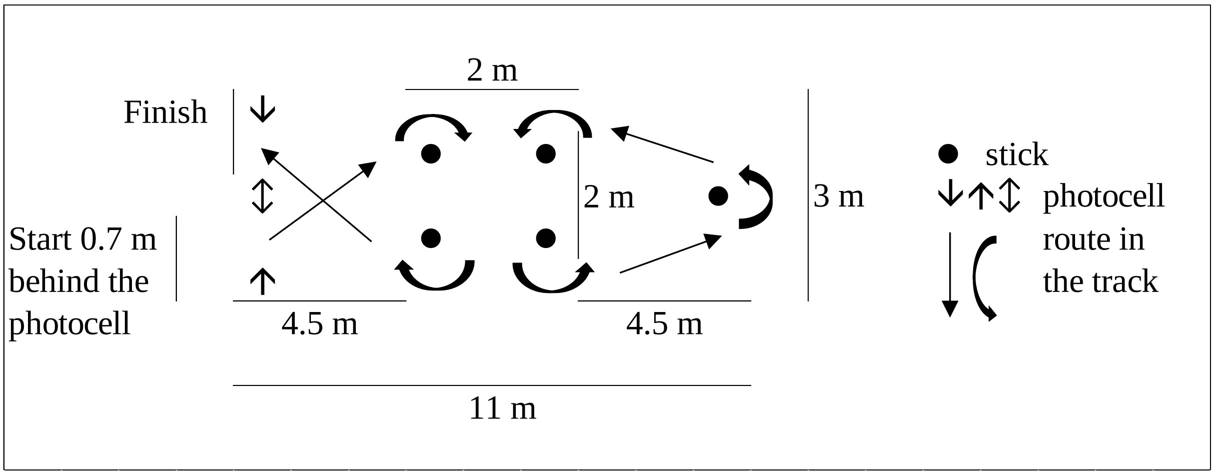
Kauanko on kulunut aikaa
Viimeisestä ateriasta ________ h
Viimeisestä kofeiinipitoisesta juomasta (kahvi, tee, kolajuoma) ________ h
Viimeisestä alkoholipitoisesta juomasta __________ h / vrk

Kahden edeltävän päivän harjoitukset:
Eilisen päivän harjoitus: ____
Sitä edeltävän päivän harjoitus: ____

Olen vastannut kysymyksiin rehellisesti parhaan tietämykseni mukaan,

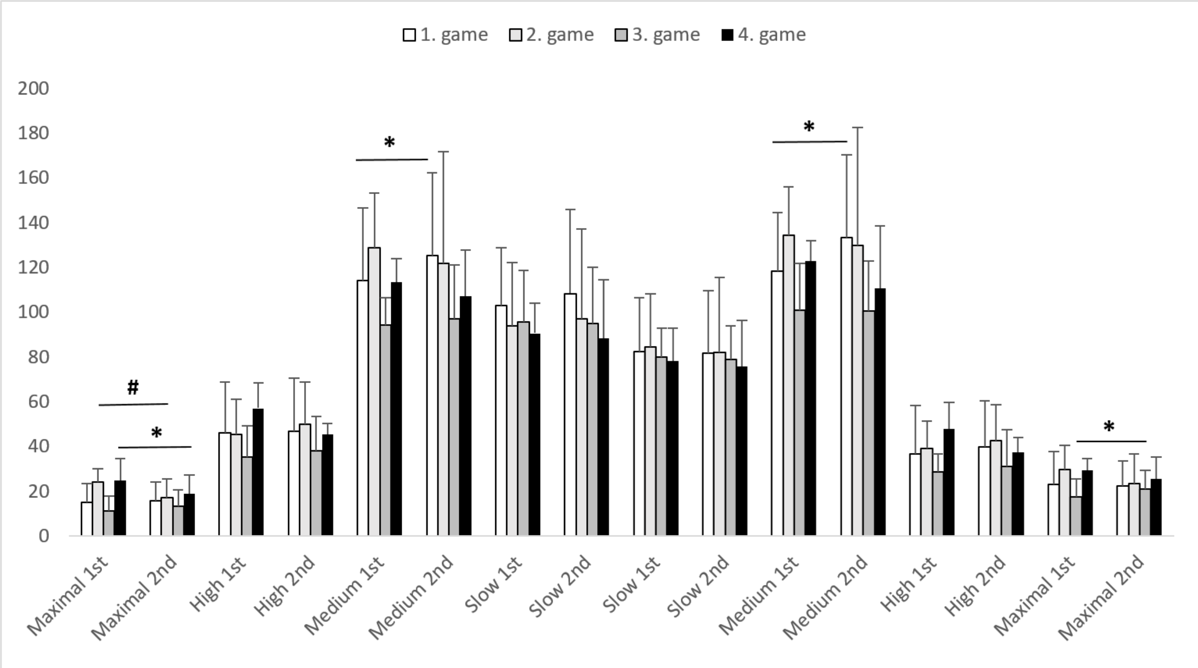
Päivä: __________________ Allekirjoitus:____

12.2 Appendix 2 – Agility test



Agility test included four 90° turns and one steep turn. The arrows show the route from the start to the finish. Start line was 0.7 m behind the first photocell, and the finish line between the photocells. The distances of sticks and photocells were all fixed.

12.3 Appendix 3 – Acceleration and deceleration in the futsal games



Accelerations and decelerations in four futsal games. There was only three points where results changes between the halves (* $p < 0.05$), and one where the result likely changed (# < 0.10).