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PLAYERLOAD™ AND HEART RATE RESPONSE TO SMALL-SIDED GAMES SPECIALIZED TO ADDITIONAL FIELD PLAYER RULE IN HANDBALL

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Aim. This study aimed to investigate PlayerLoad and heart rate responses of handball-based small-sided games which specifically designed with additional field player rule. **Materials and Methods.** Thirteen well-trained female handball players (2 goalkeepers, 2 pivots, 4 wings, and 5 backs) participated in this study. A total of eight Small-sided games (SSGs) on two different training days with separated at least 48-hour were conducted. SSGs executed with the inclusion of two each 5 vs 6 and 7 vs 6 handball specific games that mimic the numerical inferior or superior situations in game-play. PlayerLoad, acceleration, deceleration and change of direction were established by a wearable IMUs and heart rate monitored with a chest band. **Results.** There was no significant difference between $PlayerLoad_{total}$, PlayerLoadmin-1, HR_{max}, HR_{avr}, and HIE parameters during the SSGs that separated by two testing days. No significant differences were found in $PlayerLoad_{total}$, PlayerLoadmin-1, HR_{max}, and HR_{avr}, parameters attained from the main and opponent team. Results showed no significant differences between all 5 vs 6 and 7 vs 6 SSGs. There was a significantly lower $PlayerLoad_{total}$ in the goalkeepers than backs, wings and pivots. The mean and maximum heart rate of back players was significantly lower than wings and pivots. **Conclusion.** Current study set out the examiner that if tactical innovations in playing situations numerical inferiority or superiority situations 7vs6 and 5vs6, will make the difference in players' physical efforts. Because of the raised usage of this tactical variations, recent studies only focused to technical variables of playing with no goalkeeper and additional field player. Therefore, it is crucial to obtain clear knowledge how to affect the players as physically. Hence, a definite need for revision of the training demands of the goalkeepers in handball.

Keywords: *high intensity events, handball, inertial measurement units Small-sided games.*

Introduction

Handball is an intense team sport that involves accelerations, deceleration, and change of directions actions depended on ball or opponents' position which demands higher levels of internal and external loads [9, 20]. Determination of external load was particularly limited with the only measure to the time motion characterize of the players in handball likewise other indoor sports [18]. It has been noted that lower total distance covered and running pace than basketball and football [17, 21]. However, it has been reported that players performed 279 change of directions and 485 high-intensity movements [4] and this method clearly ignores the short high-intensity activities in the small space such as change of directions, jumping, throwing, tackles for the defensive phase. Recently, inertial measurement units (IMU) provide monitoring the PlayerLoad and high-intensity events as reliable and precise during training and math-play [13]. Several studies have determined the PlayerLoad and high-intensity pattern by using IMU sensors in elite team handball [13, 23]. Usage of small-sided games is an important training concept that covered requirements of high physical and technical demands of playing handball. Previous studies have considered to implements of handball specific small-sided games (SSGs) with different court size [5, 6], contact or non-contact playing rules [7, 8], and playing variations such as 3 vs 3 and 6 vs 6 [15]. Following a serial change of rules by International Handball Federation [10], the attacking team can play with an additional field player after taking the goalkeeper bench which resulted in an empty goalie. Therefore, during the 2-min penalty teams have got an opportunity to tolerate numerically inferiority with an additional field player. Almost three of four teams have been applied to change goalkeeper with a field player in numerical inferiority to equilibrate against the opponent with an empty goalie risk [19]. Also, some of the teams that troubles in the attacking organizations and problems to scoring have gained to chance attack numerically superiority with the same rule. As our knowledge, no previous study has investigated monitoring the physical response of additional field player during the numerical inferiority or superiority situations. Therefore, this study aimed

to investigate PlayerLoad and heart rate responses of handball-based small-sided games which specifically designed with additional field player rule.

Materials and Methods

Thirteen well-trained female handball players participated in this study. Two goalkeepers, two pivots, four wings, and five backs members of the same club which attend super league of national competition trained at least 90 minutes lasted practice of 7 session/week. Volunteers gave their written informed consent after they notified the description of the study design. Prior to the experiment, the study protocol approved by the Local Ethical Committee.

A total of eight SSGs were performed on two different training days with separated at least 48-hour (scheduled at the same time of the day). Every training day four SSGs executed with the inclusion of two each 5 vs 6 and 7 vs 6 handball specific games that mimic the numerical inferior or superior situations in game-play (+1 player and an empty goalie). Each SSG completed as eight minutes play with break a four-minutes recovery similar to the previous studies [2]. The training sessions started with a 20-minute standardized warm-up that starts a general running and stretching exercise, follows by handball specific passes and shooting exercises. The rules of the handball specific exercises applied as same as the official handball games except for the quick ball replacement after the ball thrown away by shooting and 7-m penalty does not execute in case of occurs a penalty situation. Substitutions with the goalkeeper and the additional field player were paid attention especially because of its results with 2-min suspension. Verbal encouragement provided for the player's maximum effort and maintain the playing pace high.

All players suit up a manufacturer-made vest (Catapult Sports, Melbourne, Australia) that included reliable IMUs (OptimEye S5, Catapult Sports, Australia) at the posterior side of the upper trunk [14]. Participants also wore a compatible chest band for the monitoring heart rate (Polar T31coded, Finland). PlayerLoad^{TM} calculated from the below equation which defined as the square root of the sum of the instantaneous rate of change in acceleration from three vectors divided by a scaling factor of 100 [23].

$$PlayerLoad^{TM} = \sqrt{\frac{(a_x - a_{x-1})^2 + (a_y - a_{y-1})^2 + (a_z - a_{z-1})^2}{100}}$$

All accelerations, decelerations, and change of directions that over 2.5 m.s-1 were established and summed from inertial movement analysis (IMA) sensor for referring to as high-intensity events (HIE) [13]. PlayerLoad^{TM} split into four bands as 0-1, 1-2, 2-3, and 3-4 as given defaulted in manufacturer software (OpenField, Catapult Sports, Australia). Achieved highest heart rate (HR) during the repeated high-intensity activity considered maximal heart rate (HR_{max}) and HR zones have taken as < 50 %, 50–70 %, 70–90 % and > 90 % of HR_{max} regarding the previous studies [5].

Statistical analysis

Acquired data statistically analyzed by using SPSS 25 software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY). Data are presented as mean ± and standard deviation (SD) and $p < 0.05$ set up as significance level. Descriptive data were generated for all SSGs. A one-way analysis of variance (ANOVA) was calculated on player positions' and drills' PlayerLoad^{TM}, heart rate parameters, and high-intensity events (HIE) performed Bonferroni posthoc test in case of significant differences between groups. Comparisons between first and second testing day PlayerLoad^{TM} and heart rate results and main team (that played with additional field player) and the opponent team were made using the non-parametric Mann Whitney U test.

Results

There was no significant difference between $PlayerLoad_{total}$, $PlayerLoad.min^{-1}$, HR_{max}, HR_{avr}, and HIE parameters during the SSGs that separated by two testing days (respectively, p = .440, .787, .482, .080, and 0.549). No significant differences were found in $PlayerLoad_{total}$, Player $Load.min^{-1}$, HR_{max}, and HR_{avr}, parameters attained from the main and opponent team (respectively, p = .324, .218, .788, and .231). Table 1. Summarized all SSGs PlayerLoad^{TM} and heart rate responses playing with additional field player rule. Results showed no significant differences between all 5 vs 6 and 7 vs 6 SSGs. PlayerLoad^{TM} and heart rate outcomes according to the player positions are presented in Table 2. There was a significantly lower $PlayerLoad_{total}$ in the goalkeepers than backs, wings, and pivots. The mean and maximum heart rate of back players was significantly lower than the wings and pivots (Table 2).

High intensity events and PlayerLoads according to four bands with different intensities for all players' positions demonstrated in the Figure 1.

The back players exposed the most HIE when compared with all other playing positions. However, they also produced significantly high rate

Table 1

Internal and external load of SSGs during numerical superiority and inferiority with additional field player rule

	Day 1				Day2			
	1st 5:6 (+1 additional player)	**2nd 5:6** (+1 additional player)	**1st 7:6** (+1 additional player)	**2nd 7:6** (+1 additional player)	**3rd 5:6** (+1 additional player)	**4th 5:6** (+1 additional player)	**3rd 7:6** (+1 additional player)	**4th 7:6** (+1 additional player)
PlayerLoad$_{total}$	60.60 ± 6.32	65.99 ± 10.42	56.63 ± 8.21	62.09 ± 8.75	67.28 ± 9.27	64.73 ± 14.56	58.12 ± 10.75	66.20 ± 7.29
PlayerLoad·min^{-1}	7.64 ±0.73	8.36 ± 1.51	6.88 ± 1.00	7.50 ± 1.06	8.25 ± 1.14	7.80 ± 1.75	6.95 ± 1.29	8.10 ± 0.89
HR$_{max}$ (beat.min^{-1})	181.5 ± 10.09	191.00 ± 12.04	187.37 ± 13.88	184.12 ± 17.22	182.85 ± 12.20	184.71 ± 22.97	180.25 ± 19.37	186.12 ± 17.83
HR$_{avr}$ (beat.min^{-1})	156.59 ± 10.38	170.77 ± 15.54	162.45 ± 12.21	164.68 ± 17.37	155.85 ± 10.03	157.59 ± 16.74	153.24 ± 20.00	159.86 ± 17.71
Heart Rate$_{max}$ (%)	79.79 ± 6.87	88.16 ± 4.38	82.95 ± 7.48	83.70 ± 7.30	78.63 ± 5.50	78.00 ± 4.09	76.10 ± 9.21	78.99 ± 5.13

Table 2

Internal and external load of SSGs according to the player positions

	Backs (n = 33)	**Wings (n = 29)**	**Pivots (n = 12)**	**Goalkeepers (n = 8)**
PlayerLoad$_{total}$	60.98 ± 16.81	62.24 ± 14.45	63.56 ± 8.82	52.05 ± 7.39 *
PlayerLoad·min^{-1}	7.48 ± 2.08	7.58 ± 1.77	7.79 ± 1.16	6.34 ± 0.89 *
HR$_{max}$ (beat.min^{-1})	178.09 ± 19.18 **	188.06 ± 19.43	190.16 ± 9.30	185.87 ± 6.49
HR$_{avr}$ (beat.min^{-1})	154.88 ± 21.51 **	165.12 ± 18.25	166.83 ± 13.33	161.09 ± 7.07
Heart Rate$_{max}$ (%)	79.89 ± 10.23	80.89 ± 9.38	79.20 ± 10.21	82.86 ± 4.39

* Significantly lower than Backs, Wings and Pivots; ** Significantly lower than Wings, Pivots and Goalkeepers.

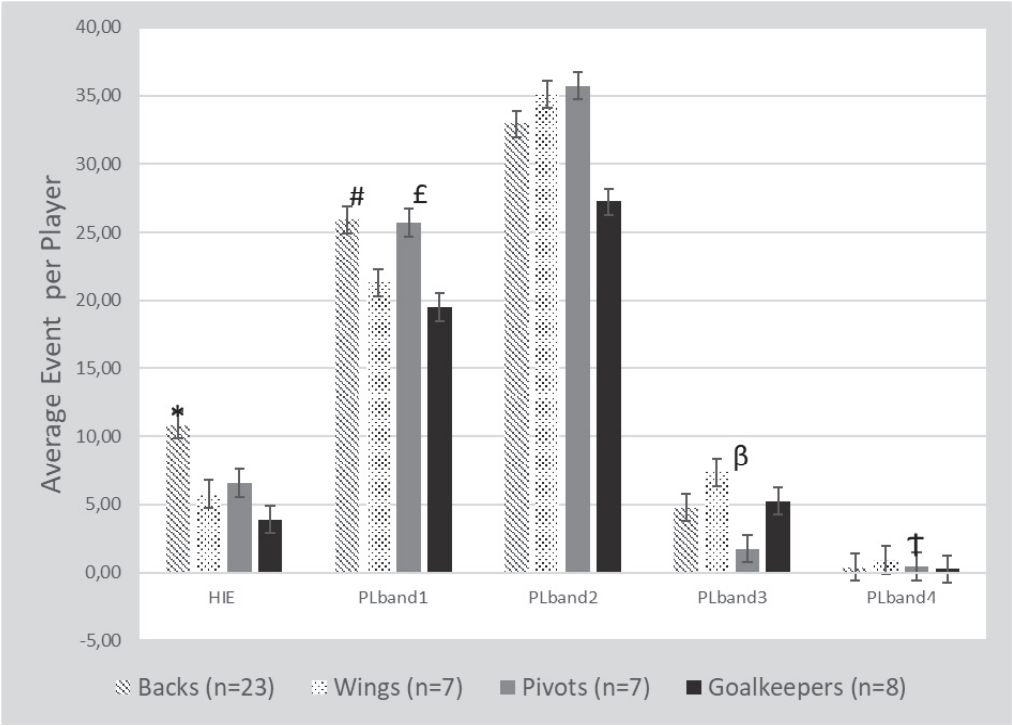

Fig. 1. High-intensity events and distributions of PlayerLoad^{TM} bands according to the player positions.
The mean difference is significant at the 0.05 level. * significantly higher than wings, pivots, and goalkeepers; # significantly higher than wings, and goalkeepers; £ significantly higher than goalkeepers; β significantly higher than pivots; † significantly higher than backs, and goalkeepers

of PlayerLoad in the lowest PLband compared to wings and goalkeepers. Efforts of the pivots for PLband 3 and PLband4 were significantly lower than all other playing positions (Figure 1).

Discussion

In this study, we investigated whether additional field player plays a role in the internal and external load associated with numerical inferiority or superiority. This is the first study to undertake the physical analysis of the additional field player rule from the perspective of handball specific games. Our results show that PlayerLoad^{TM} and HR responses differed neither 5 vs 6 nor 7 vs 6 SSGs whereas finding significant changes depending on the player positions.

The findings from this study indicated that no significant differences between PlayerLoad and heart rate response of the handball specific drills. The similar effects of both numerical inferiority and superiority situations suggested that learning is not an affecting factor and player group has proper readiness to these tactical variations. However, no control group played with 6vs6, so the findings of the present study could not compare. The pacing strategy and tactics of playing routine 6 vs 6 have possibly resulted in different internal and external loads.

Previous studies have provided important information on the relation between SSGs and PlayerLoad in handball. It has been reported that different court sizes affect the PlayerLoad by increased distance covered in the larger playground during SSGs [5]. The study investigated that contact and non-contact SSGs, Iacono et al., have been demonstrated that both designed SSGs resulted in similar heart rate responses however non-contact SSG enables sprint and higher running pace than contact SSG [8]. As a training regimen, it was found SSGs have beneficial in-season physical improvements on agility and standing throwing velocity [5]. Buchheit et al., has found similar positive effects of handball specific games and repeated sprint training to the physical performance [3]. However, handball specific games may be considered as the preferred training approach for improving technical variables besides fitness.

Although to performed repeatedly sprint running to the substitution area, goalkeepers showed significantly lower PlayerLoad^{TM} when compare to the other three playing positions. Nevertheless, similar heart rate responses of the goalkeepers revealed that increased internal loads. Also, HR_{max} % results of all playing positions were almost equivalent regardless of aerobic endurance, physical and body composition divergent of the players' positions conflicting with the previous study which measured lowest heart rate response in the goalkeepers [16]. Different from the findings presented here Corvino et al., showed that higher HR response by performing 4vs4 SSGs in different court sizes [6]. The observed increase in HR could be attributed to players have to be active in a vigorous place than their originally played space. However, our HR results reflect those of Povoas et al., who also showed a similar hear rate response (82 ± 9.3 % of HR_{max}) during the match-play [21]. Interestingly, a recent study conducted by Luteberget et al., have found that external load (PlayerLoad.min^{-1}) was significantly higher in backs and goalkeepers showed the lowest one [13]. However, they collected the data from the whole game whereas our study performed 8-min SSGs. Sibila et al., also found the lowest distance covered and long-standing time during the match play [22]. Most of the researchers underestimated to PlayerLoad^{TM} of goalkeepers by exclusion during the study despite the highest average field time. Goalkeepers do not play in a particular zone; they have to sprint to the sideline for immediate substitutions. Hence, unsteady numerically attacking formations may result in the difference PlayerLoad^{TM} according to the player positions. Supporting findings of this explanation by Korte and Lames have observed that attacking without goalkeeper such as 7 vs 6 and 5 vs 6 (with additional field player) significantly longer offense time and more passes when compared to 6 vs 6 [11].

An IMU-based study showed that two-way players (both defense and offense) perform 3,90 ± 1,58 HIE/min and it differs according to the playing positions (respectively higher backs, pivots, wings, and goalkeepers). Interestingly, players who only play in the offense exposed higher PlayerLoad.min^{-1} and HIE.min^{-1} [13]. These findings affecting the external load and HIE may be related to repeated substitutions during the game including 2-min penalties and tactical variations. Despite these internal and external PlayerLoad variations, there was a dissimilar difference in the PlayerLoad bands and HIE within playing positions. Back players showed higher levels in the lower intensity PlayerLoad^{TM} band whereas wings exposed to the higher PlayerLoad^{TM} band categories when compared to all other playing positions. This result may be explained by the fact that backs dominate the interplay and pass for playmaking opposite to all defense formations [11]. Another

possible interpretation for this is that wing players frequently performed high accelerations for the transition to attack to defense or vice versa. In the present study, the exposition of more HIE of wing players is likely to be related to 7 vs 6 attacking centralization which is crucial to immediate substitution after the shooting. Wings are naturally closer positions to the substitution area that resulted in the first option the sprint back for change with the goalkeeper. Also, it is obviously preferable to finish the attacks from the opposite side of the changing area therefore wings presented higher values of the PlayerLoad™ band and HIE.

Conclusion

The current study set out the examiner that if tactical innovations in playing situations numerical inferiority or superiority situations 7 vs 6 and 5 vs 6, will make the difference in players' physical efforts. Because of the raised usage of these tactical variations, recent studies only focused on technical variables of playing with no goalkeeper and additional field player [1, 12]. Therefore, it is crucial to obtain a clear knowledge of how to affects the players as physically. Hence, a definite need for revision of the training demands of the goalkeepers in handball.

The rules give the coaches a lot of options to prepare specific tactics concerning 2-min suspension that occurs disadvantages by numerical inferiority. By apply the substitution goalkeeper and additional field player, teams can gain an advantage to scoring goals in case of attacking difficulties and also at the end of the half or match when the teams needed to score a goal. However, during the execute these tactical changes it requires a lot of precaution and readiness of immediate substitution with sprinting to the sideline.

The major limitation of this study is the unobserved internal and external load variables from the opposite team of playing 7 vs 6 and 5 vs 6. However, these results may not be comparable with current literature because of the lacking the evaluation of locomotion data from additional field player tactics and 6 vs 6 formations. Further studies need to be carried out to establish this tactical flexibility in the match-play. Furthermore, it would be interesting to compare these variations within performance indicators such as scored or missed shootings taken from different playing positions and technical errors, etc.

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РАСЧЕТ ИГРОВОЙ НАГРУЗКИ И СЕРДЕЧНЫХ СОКРАЩЕНИЙ ВО ВРЕМЯ ИГР НЕПОЛНЫМ СОСТАВОМ С ЭЛЕМЕНТАМИ ГАНДБОЛА С УЧЕТОМ ПРАВИЛА ДОПОЛНИТЕЛЬНОГО ИГРОКА

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Цель. Данное исследование направлено на изучение игровой нагрузки и частоты сердечных сокращений в играх неполным составом с элементами гандбола, которые разработаны с учетом правила дополнительного полевого игрока. **Материалы и методы.** В исследовании приняли участие 13 профессиональных гандболисток (2 вратаря, 2 центральных

игрока, 4 игрока фланга и 5 защитников). В общей сложности было проведено восемь игр неполным составом в два разных тренировочных дня с перерывом не менее 48 часов. Две игры проводились в особом формате 5 против 6 и 7 против 6 с целью имитации ситуации численного превосходства игроков в команде. Нагрузка на игрока, ускорение, замедление и изменение направления определялись с использованием инерциального измерительного блока, частота сердечных сокращений контролировалась с помощью кардиопояса. **Результаты.** Параметры $PlayerLoad_{total}$, PlayerLoadmin-1, HR_{max}, HR_{avr} не продемонстрировали статистически значимой зависимости от нагрузок высокой интенсивности во время игр неполным составом, разделенных двумя днями отдыха. Данные, полученные для параметров $PlayerLoad_{total}$, PlayerLoadmin-1, HR_{max}, HR_{avr} в основной команде и команде противника, не показали статистически значимых различий. Существенных различий также не было обнаружено для игр, проведенных составом 5 против 6 и 7 против 6. Показатель $PlayerLoad_{total}$ у вратарей был значительно ниже, чем у защитников, игроков фланга и центральных игроков. Средняя и максимальная частота сердечных сокращений у защитников была значительно ниже, чем у игроков фланга и центральных игроков. **Выводы.** Данное исследование показало зависимость между тактическими нововведениями в игровых ситуациях численного превосходства (игра в составе 7 на 6 и 5 на 6) и физическими усилиями игроков. Из-за частого использования данных тактических вариаций последние исследования преимущественно сосредотачивались на технических элементах игры без учета фактора вратаря и дополнительного полевого игрока. Таким образом, необходимо получить четкое представление о том, как воздействовать на игроков с точки зрения физической подготовки. Исследование также выявило потребность в пересмотре требований к тренировкам вратарей-гандболистов.

Ключевые слова: *нагрузки высокой интенсивности, гандбол, инерциальный измерительный блок, игра неполным составом.*

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