Original Article

Acute physiological responses to simulated games with different defensive formations in team handball: 6:0 versus man-to-man

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Abstract

Background and Aim: Although 6:0 and man-to-man defensive formations in team handball (TH) are widely used, there is little information with regard to their physiological impact. Therefore, the aim of the present study was to examine the acute effect of two simulated games, one using 6:0 and the other man-to-man, on measures of neuromuscular performance in young TH players.

Methods: Eleven TH field players (experience 4.3 ± 0.7 years, training 6.5 ± 1.6 h/week, age 15.1 ± 1.0 years, body mass 73.7 ± 9.7 kg, stature 177 ± 7 cm), all members of an academy of a first league club, played two 20-min simulated matches (separated by 2 weeks). They were tested before and after each match for handgrip strength (HS), squat jump (SJ) and 20-m sprint (0–10 m and 10–20 split time). Two-way ([prematch vs. postmatch] × [6:0 formation vs. man-to-man formation]) repeated measures analysis of variance examined differences.

Results: We observed main effect of match on HS, 20 m sprint and 0–10 split time ($P \leq 0.037$, $\eta^2 \geq 0.37$), and of formation on 20 m sprint and 0–10 split time ($P \leq 0.002$, $\eta^2 \geq 0.65$). In addition, there was a significant interaction between match and defense formation on SJ and 20 m sprint ($P \leq 0.047$, $\eta^2 \geq 0.34$). The formation 6:0 and man-to-man resulted in similar mean (179.8 ± 7.2 vs. 180.0 ± 7.0 bpm) and peak heart rate (193.7 ± 4.6 vs. 196.0 ± 8.8 bpm).

Conclusion: The findings of this study indicate that the choice of a defensive formation in TH may result in different physiological responses that are associated with neuromuscular performance. Knowledge about the physiological impact of each formation can help coaches to optimize the use of the various formations during the game and to use them during training in order to elicit different physiological responses.

Key words: Handgrip strength, heart rate, sprint, squat jump, team sport

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INTRODUCTION

Although the physical and physiological profile of team handball (TH) has been well studied,[1-3] there is less information about the physiological demands of match play. Chelly *et al*.[4] examined heart rate (HR) responses to 2 × 25 min match in adolescents, revealing mean HR of 82% of maximal HR (HR_{max}), and suggested modification of playing tactics as a mean to sustain performance. In addition to HR recording, match demands have also been assessed by means of monitoring changes in motor activity profile throughout the match (e.g., comparison between first and second halves, and among 5 min periods within each half).[1,4-6] Póvoas *et al*.[1] observed a decrease in running intensity, HR, time spent in high-intensity activities, which were attributed to neuromuscular fatigue. Based on these findings, recently, the degree and type

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of neuromuscular fatigue development after intense exercise periods and towards the end of real matches was examined,[6] and found that jumping ability, sprinting speed, and progressive intermittent exercise performance were lowered immediately after the game. Additionally, sprint performance was lowered after an intense period in the second half. Neuromuscular performance and time-motion profile alterations during the match indicated that the players experience temporary and permanent fatigue during match-play.

The above mentioned studies on match analysis have improved our understanding of the physiological demands during match play, but there is still little information with regards to the neuromuscular changes occurring during the game play in young players. Zakas *et al*.[7] examined the effect of a TH match on flexibility and found that significant increased range of motion in all lower limbs' joints and in trunk flexion. Neuromuscular fatigue in sports is usually evaluated by measures of handgrip muscle strength (handgrip strength [HS]),[8,9] vertical jump[8,10] and sprint performance.[10] These measures are widely used to evaluate physical fitness in TH[11-13] and discriminate TH players by performance level.

It has also been shown that the activity motor profile is different in both phases of the match (attack and defense) and that exercise intensity only decreases in the defense phase, probably due to a higher amount of time spent in high-intensity activities in this phase of the match.[1] Nevertheless, there are no studies that evaluate the physical and physiological impact of different defense formations. The different defensive formations are classified based on the initial defensive system structure and on the role of each defender.[14] Thus, we can find individual (man-to-man), zone (6:0, 5:1, 3:2:1, 4:2, 3:3 and 5:1) or combined defense formations (5 + 1, 4 + 2 and 3 + 3). In order to prevent the attack to adapt to the defense formation, TH teams usually use several defense formations during the matches.[14,15] Individual defensive formation is stated to be more physical demanding as the defender has to closely follow the attacker throughout all the match time, while zone defense formations, particularly, 6:0, are stated to be less physically demanding due to greater distance between the players and more interchanging in defense tasks leading to less distance covered and less intensity work performed.

Nevertheless, man-to-man and 6:0 defensive formations are widely used in TH, there is no information with regard to their physiological or neuromuscular impact on players' performance. Such knowledge might help coaches and trainers to optimize the use of these defense formations in match and in training. Therefore, the aim of this study was to examine the acute effect of using 6:0 and man-to-man defense formations, on physiological response and neuromuscular performance in young TH players.

MATERIALS AND METHODS

Study design and participants

To examine the effect of the two defense formats (man-to-man and 6:0)[14,15] on the acute physiological and neuromuscular responses to a simulated handball match, we used an experimental study design, in which participants were tested before (baseline conditions) and after two simulated matches, one using man-to-man defense formation and other using 6:0 [Figure 1]. The physiological response was evaluated through continuous monitoring of the HR during the matches. Neuromuscular evaluations, which involved measuring HS, squat jump (SJ) and sprint time, were designated as the dependent variables. The defense format (6:0 vs. man-to-man) and time (pre- vs. post-match evaluations) were designated as the independent variables. The study protocol was performed in accordance with the ethical standards from the Declaration of Helsinki in 2013 and approved by the local Institutional Review Board and by the club officials. Informed written consent from the parents and players were obtained.

Eleven TH outfield players, all members of an academy of a first league club, participated to this study during the competitive period of season 2012–2013 [Table 1]. The participants played two 20-min simulated matches, separated by a 10 min half-break, with no substitutions allowed, within 2 weeks, in an indoor court under similar neutral environmental conditions (temperature 20°C and humidity 45%) between 7 and 9 pm on week days. We advised the players to maintain their normal nutritional habits during the testing, and asked the coaches to continue the usual training schedule. The players were tested before the match after performing a standardized warm-up consisting of 10 min running, 5 min stretching exercises and 5 min sprinting exercises, and within 3 min after each match for HS, SJ and 20-m sprint (acceleration phase 0–10 m, sprint 0–10, and maximum speed phase 10–20 m, sprint 10–20), in this order. To attend the time frame, several testing stations were set. 1-week prior to the measurements in the court, the participants visited our laboratory, where they were examined for anthropometric characteristics.

Anthropometric characteristics

In the first evaluation session, height and body mass were measured with subjects barefoot and in minimal clothing. An electronic weight scale (HD-351 Tanita, Illinois, USA) was employed for body mass measurement (in

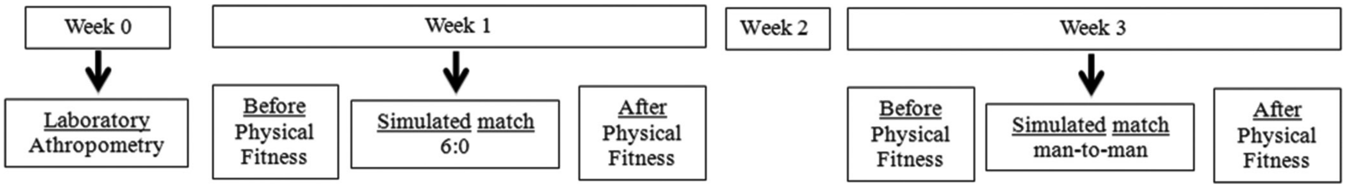

Figure 1: Schedule of testing sessions

Table 1: Anthropometric characteristics of participants (*n*=11)

Age (years)	Body mass (kg)	Height (cm)	Playing experience (years)	Training (h/weeks)
15.1±1.0	73.7±9.7	177±7	4.3±0.7	6.5±1.6

Values were presented as mean±SD. SD: Standard deviation

the nearest 0.1 kg) and a portable stadiometer (SECA, Leicester, UK) for height in the Frankfurt plane (0.001 m). Chronological age for each participant was calculated using a table of decimals of year.[16]

Isometric handgrip strength test

The isometric HS testing included two measures, right and left handgrip (intraclass correlation coefficient [ICC] =0.94–0.98).[17] In the HS test, after having fitted the dynamometer to their hand so that the bar was rested on the phalanx of the index and ring finger, the participants were instructed to squeeze the handle of a digital handgrip dynamometer (Takei, Tokyo, Japan) as hard as possible standing with their elbow bent at approximately 90°.

Squat jump

Participants were tested in SJ twice.[18] They started in a standing position with both feet together and arms in the waist and were asked to jump as high as possible from the initial squat position. The depth of the initial squat position was set by the tester and participants were asked to land as close as possible to their point of take-off. Flight time was used to calculate the change in the height of the body's centre of gravity.[19] Height of jump was estimated using the Opto-jump (Microgate Engineering, Bolzano, Italy) (ICC = 0.91 and coefficient of variation [CV] =3.3%).[20]

20 m sprint

Also, participants performed 20 m sprint twice and the best time was recorded. Sprint was timed using a photocell TC Timing System (Brower Timing Systems, Utah, USA). The use of three pairs of photocells, set at 0, 10 and 20 m allowed to record performance of split 0–10 m and split 10–20 m, in addition to 20 m sprint. The photocells were placed at the belt height in order the legs not to break the light beam according to manufacturer's guidelines and players started their attempts from a standing position 0.5 m behind the first pair of photocells (ICC = 0.91 and CV = 2.9%).[21] The two repetitions of each of the neuromuscular tests were performed with approximately a 10–15 s interval of rest and at least 90 s of rest between the different tests. The best values were used for further analysis.

Heart rate monitoring

During the simulated matches, team's coach cheered vigorously his players in order to imitate as much as possible the real conditions of a match. HR was continuously monitored with Team2Pro (Polar Electro Oy, Kempele, Finland). All players were familiar with HR monitors, because they had already used them during previous testing sessions. We used two indices of HR for our analysis, the peak value (HR_{peak}) and the mean value (HR_{mean}), which were expressed in absolute values (beats per minute, bpm) as well as % of theoretical HR_{max}. We used the recently developed age-based equation "223–1.44 × age" to predict HR_{max},[22] because the traditional "220-age" formula seems to overestimate actual values.

Statistical analysis of data

Statistical analyses were performed using IBM SPSS version 20.0 (SPSS, Chicago, USA). Data were expressed as mean and standard deviations of the mean. Only the best score of each test (HS, SJ and sprint time) was included in the data analysis and the parametric analysis techniques were used. A two-way repeated measures analysis of variance (ANOVA) with a subsequent Bonferroni *post-hoc* test (if differences between groups were revealed) was used to examine differences between before and after the simulated match in two occasions (6:0 vs. man-to-man). To interpret effect sizes (ES) for statistical differences in the ANOVA we used eta square classified as small ($0.01 < \eta^2 \leq 0.06$), medium ($0.06 < \eta^2 \leq 0.14$) and large ($\eta^2 > 0.14$).[23] The level of significance was set at $\alpha = 0.05$.

RESULTS

The comparison between pre-match and post-match values revealed a significant main effect with regards to HS ($F_{(1,10)} = 5.81$, $P = 0.037$, $\eta^2 = 0.37$), 20 m sprint ($F_{(1,10)} = 17.93$, $P = 0.002$, $\eta^2 = 0.64$) and 0–10 m split time ($F_{(1,10)} = 11.32$, $P = 0.007$, $\eta^2 = 0.53$), but not in SJ ($F_{(1,10)} = 0.29$, $P = 0.605$, $\eta^2 = 0.03$) and 10–20 m split time ($F_{(1,10)}$ =0.71, P = 0.420, η^2 = 0.07) [Figures 2 and 3]. Compared with pre-match, HS (−2.5 kg [−4.8; −0.2], mean difference [95% confidence interval]) and performance in 20 m sprint (0.05 s [0.02; 0.07]) and 0–10 m split time (0.04 s [0.01; 0.06]) decreased in post-match, whereas no significant change was observed in SJ (0.3 cm [−0.8; 1.3]) and 10–20 m split time (0.01 s [−0.01; 0.02]). ES was large in the cases of HS, 20 m sprint and 0–10 split time, medium in 10–20 m split time and small in SJ.

With regards to defense formations, there was a significant main effect on 20 m sprint ($F_{(1,10)}$ =32.82, $P < 0.001$, η^2 = 0.77) and 0–10 m split time $F_{(1,10)}$ =18.53, P = 0.002, η^2 = 0.65), but not on SJ ($F_{(1,10)}$ =1.96, P = 0.192, η^2 = 0.16), HS ($F_{(1,10)}$ =1.02, P = 0.337, η^2 = 0.09) and 10–20 m split time ($F_{(1,10)}$ = 2.77, P = 0.127, η^2 = 0.22). We observed better scores in 20 m sprint (−0.09 s [−0.12; −0.05]) and 0–10 m split time (−0.08 s [−0.12; −0.04]) during the 6:0 formation than during man-to-man formation, whereas there was no difference in SJ (−1.0 cm [−2.5; 0.6]), HS (−1.2 kg [−3.7; 1.4]) and 10–20 m split (−0.01 s [−0.02; 0]). ES was large in the cases of 20 m sprint, 0–10 m split time, 10–20 m split time and SJ, and medium in HS.

In addition, there was a significant interaction between match and defense formation on SJ ($F_{(1,10)}$ =5.14, P = 0.047, η^2 = 0.34) and 20 m sprint ($F_{(1,10)}$ =7.17, P = 0.023, η^2 = 0.42), but not on HS ($F_{(1,10)}$ =1.13, P = 0.312, η^2 = 0.10), 0–10 m ($F_{(1,10)}$ =1.10, P = 0.319, η^2 = 0.10) and 10–20 m split time ($F_{(1,10)}$ =4.41, P = 0.062, η^2 = 0.31). ES was large in SJ, 20 m sprint and 10–20 m split time, and medium in HS and 0–10 m split time.

With regards to HR responses to simulated matches, no difference was observed. The formation 6:0 and man-to-man resulted in similar mean (179.8 ± 7.2 vs. 180.0 ± 7.0 bpm) and HR_{max} (193.7 ± 4.6 vs. 196.0 ± 8.8 bpm).

DISCUSSION

To the best of our knowledge this is the first study to examine acute physiological and neuromuscular responses to a handball match in young TH players using different defense formats. The main findings were (a) a main effect of match (pre vs. post) on HS, 20 m sprint and 0–10 split time, (b) a main effect of formation on 20 m sprint and 0–10 split time, and (c) an interaction between match and defense formation on SJ and 20 m sprint. The latter finding indicated that the two defense formations used in the present study resulted in different neuromuscular responses with regard to two very important abilities for TH (sprinting and jumping).

The comparison between pre- and post-match scores did not reveal any difference in jumping performance. Previous studies that examined the effect of taekwondo match on jumping ability had shown decreased jumping performance in post-match,[8] and this decrease was attributed to high neuromuscular activation of lower limbs. However, compared with taekwondo the duration

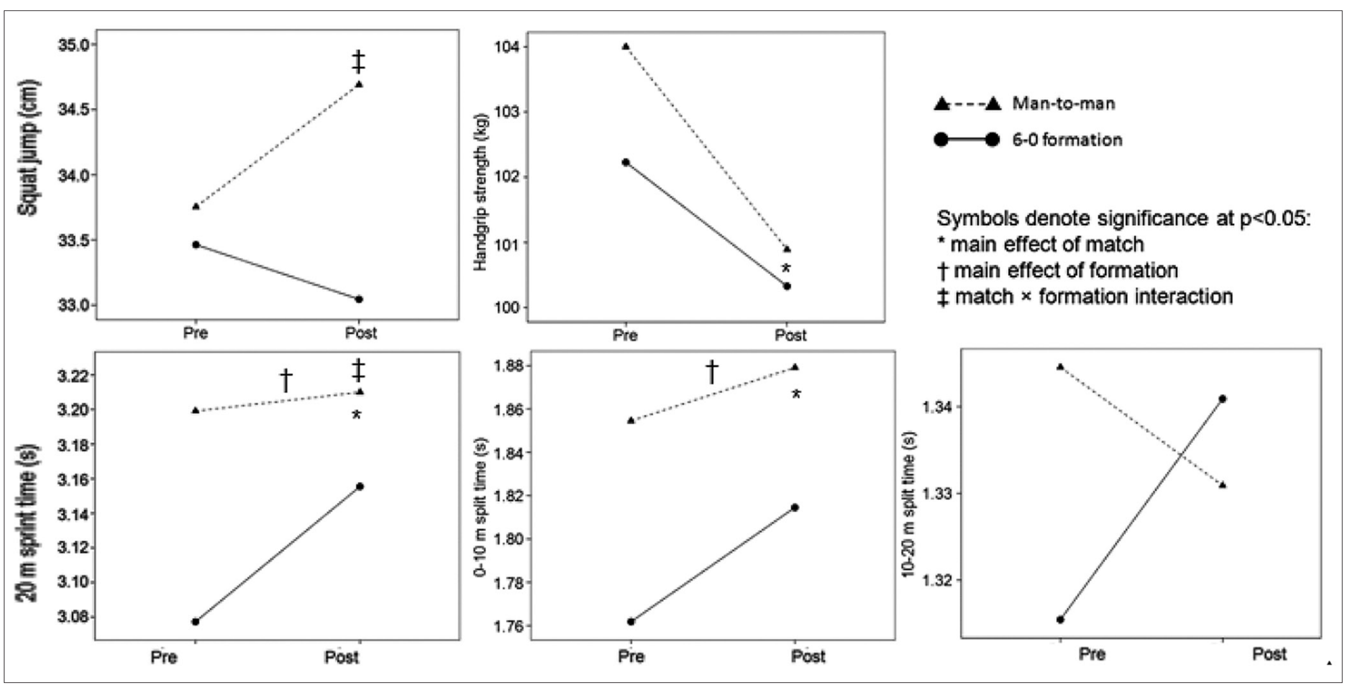

Figure 2: Main effects of match (pre vs. post) and formation (man-to-man vs. 6:0), and their interaction on squat jump, handgrip strength and 20 m sprint performance

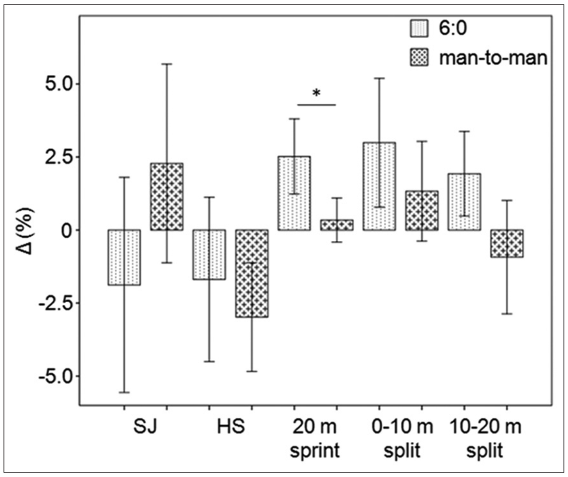

Figure 3: Percentage differences between post- and pre-match values of squat jump, handgrip strength and sprint performances according to defense formation (man-to-man vs. 6:0)

of TH match was longer, which resulted in fatigue that counterbalanced the effect of neuromuscular activation. The decrease in HS was in agreement with similar findings of taekwondo[8] and boxing matches,[9] and an interpretation for this decrease was the fatigue of upper limbs due to repeated actions.

In addition, we observed differences in sprinting performance between the two sessions of simulated matches the different defensive formats. Such variation in sprinting performance cannot be attributed neither to the period duration between matches (2 weeks) nor to expected changes in performance within competitive period. Large changes in jumping performance (~4 cm), which is correlated with sprinting performance, have been shown previously in a 7-week preparation period.[24] High intensities movements might vary between different defense formations. From a physiological point of view, in high intensity exercise most of adenosine triphosphate (ATP) resynthesis results from the breakdown of phosphocreatine and glycogen, and energy is provided using anaerobic metabolism.[25] However, it is well known that if these high intensity efforts are repeated for a prolonged period, the contribution of these processes in the resynthesis of ATP loses prominence, producing an increase of aerobic metabolism.[25,26] This contribution by the aerobic metabolism does not compensate for the aerobic energy provided the system, so that decrease in performance from being unable to maintain the power output occurs.[25] This might explain the decrease of performance during match.

Limitations of the study

A limitation of this study was that due to the less sample size, we did not take into account playing positions. It has been shown that even in the age of the participants certain physical and physiological differences among playing positions exist[2,27-29] and the effects of defense formats might vary by position. Moreover, recent studies[12,30] have shown an association between body mass and physical fitness components (e.g., an excess of body mass might impact jumping and running performances), and thus, body mass is a variable that might play a role in the match-inducing fatigue. Despite these limitations, this study adds to the existing literature considering the lack of previous research to provide references about the impact of match on physiology that would have practical value to coaches and trainers.[31] Sport staff should pay special attention to the effect of defense formations on sprint performance, considering the importance of sprinting in the modern TH (e.g., for fast-breaks)[32] and the relationship between physical performances and TH skills (e.g., moving with ball).[33] Such match-induced neuromuscular fatigue might impact important skills like shooting efficiency.[34]

CONCLUSION

The findings of this study indicate that the choice of a defensive formation in TH may result in different physiological responses that are associated with neuromuscular performance. Knowledge about the physiological impact of each formation can help coaches to optimize the use of the various formations during the game and to use them during training in order to elicit different physiological responses.

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