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General Fatigue and Joint Position Sense in Male Elite Handball Players

Ermüdung und Gelenkstellungssinn bei professionellen männlichen Handballspielern

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SUMMARY

Aim. The human body's ability to sense positions of body parts in the three dimensional space is defined as the joint position sense (JPS). Worsening of JPS due to acute local fatigue in e.g. shoulder joints coincides with a decline of handball specific abilities such as throwing accuracy. The purpose of our study was to determine the influence of acute global fatigue induced by a simulated handball match on local JPS of shoulders, hips and knees. Methods. Male elite handball players (n=18) were tested before (PRE) and after (POST) a simulated handball match using an angle reproduction test in shoulders, knees, and hips, respectively. The simulated handball match comprised a distance of 4680m, 81 accelerations, 9 throws, 18 jumps, 180 ball-contacts, 234 changes in direction, 225 changes in speed in 45 minutes 27 seconds. Results. JPS in athletes' shoulders (PRE: 5.3°; POST: 8.8°; Δ: 3.4°; p=0.023) and hips (PRE: 2.8°; POST: 6.1°; Δ: 3.2°; p=0.004) decreased significantly whereas knees (PRE: 6.4°; POST: 7.3°; Δ: 0.9°; p=0.561) were not affected by the simulated handball match. Conclusion. JPS worsened after a simulated handball match in shoulders and hips of male elite handball players, but remained unchanged in athletes' knees. The decreased potential in JPS in shoulder and hip joints may impair the accuracy in throwing and speed in side cuts and could thereby have a detrimental effect in a professional handball game.

Schlüsselwörter: angle reproduction, hip, knee, shoulder, proprioception.

ZUSAMMENFASSUNG

Problemstellung. Der Fähigkeit des menschlichen Körpers, die Positionen von Körperteilen im dreidimensionalen Raum zu erfassen, wird als Gelenkstellungssinn definiert. Eine lokale Ermüdung des Gelenkstellungssinns eines Gelenks, z.B. des Schultergelenks führt zur Beeinträchtigung von handballspezifischen Fähigkeiten wie z.B. der Wurfgenauigkeit. In der vorliegenden Studie untersuchten wir den Effekt eines simulierten Handballspiels im Sinne einer globalen Ermüdung auf den lokalen Gelenkstellungssinn von Schultern, Hüften und Knien von männlichen Handballprofis. Methoden. Der Gelenkstellungssinn von 18 männlichen professionellen Handballspielern wurde vor (PRÄ) und nach (POST) einem simulierten Handballspiel mit Winkelreproduktionstests in Schulter, Hüfte und Knie erfasst. Das simulierte Handballspiel setzte sich aus einer Gesamtdistanz von 4680m, 81 Beschleunigungen, 9 Würfen, 18 Sprüngen, 180 Ballkontakten, 234 Richtungswechsel, 225 Geschwindigkeitswechsel und erstreckte sich insgesamt auf eine Dauer von 45 Minuten und 27 Sekunden. Ergebnisse. Der Gelenkstellungssinn verschlechterte sich nach dem simulierten Handballspiel signifikant in den Schultern (PRÄ: 5.3°; POST: 8.8°; Δ: 3.4°; p=0.023) und Hüften (PRÄ: 2.8°; POST: 6.1°; Δ: 3.2°; p=0.004), jedoch nicht in den Knien (PRÄ: 6.4°; POST: 7.3°; Δ: 0.9°; p=0.561) der Athleten. Diskussion. Der Gelenkstellungssinn männlicher professioneller Handballspieler verschlechterte sich in der Schulter und in der Hüfte, während keine Veränderungen im Knie festgestellt werden konnte. Die belastungsinduzierte Beeinträchtigung des Gelenkstellungssinns im Schulter- und Hüftgelenke könnte die Wurfgenauigkeit und die Geschwindigkeit von Side-cuts beeinträchtigen und könnte damit eine nachteilige Wirkung in einem professionellen Handballspiel haben.

Key Words: Winkelreproduktion, Schulter, Hüfte, Knie, Propriozeption

INTRODUCTION

The human body's ability to sense positions of body parts in the three dimensional space is defined as the joint position sense (JPS) (9). As a result of local exhaustion of a particular joint the local JPS declines, which decreases performance, strength and flexibility of the investigated joint (4,21). Global muscular exercise that mobilizes or solicits a large part of body musculature such as walking, running and cycling (or ergometer exercise) induces physiological alterations and important mechanical impacts on the musculoskeletal system likely to degrade the effectiveness of local JPS. Moreover, the conditions under which the different exercises are

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performed influence JPS in different ways (13). Several techniques to quantify JPS have been proposed in athletic and clinical settings (8,16). Although no gold standard has been established to accurately measure JPS, angle reproduction tests by gravity inclinometers are widely in use (16). Investigating the effects of acute fatigue in complex sports activities such as handball maintains difficult. Simulating a complex game such as handball in a lab using cycle ergometers or dynamic knee extensions seems to inadequately imitate the demands of a professional handball game (26).

AIM OF THE STUDY

It was the aim of this study to investigate the effect of a simulated handball game on JPS in male elite handball players to quantify the effects of acute global fatigue on local JPS of shoulder, knee, and hip joints. We hypothesized that a simulated handball game would significantly affect the athletes' JPS in the proposed joints.

MATERIALS AND METHODS

The study was designed as a single group pre-post study including nineteen male professional handball players from an Austrian premier league handball team that volunteered to participate in this trial. Each participant gave written informed consent and the study was approved by the Institutional Review Board of our university. The investigators followed the Helsinki Declaration on Ethical Principles for Medical Research Involving Human Subjects of the World Medical Association (2008).

All athletes passed through the identical staged (i.e. one player starting every 10 minutes) exertion protocol and were tested before (PRE) and after (POST) the simulated handball game. In PRE-tests height using a portable stadiometer (Seca 713, Seca Germany, Hamburg, Germany), weight without garment using a calibrated electronic digital scale (Tanita HD 327, Tanita B.V., Hoofddorp, The Netherlands) and rate of perceived exertion (RPE) were evaluated as described by Borg (3). Then a standardized warm-up was performed followed by a 20 m sprint-test using six infrared-light modules (BROWER®, TC-timing system, Brower Timing Systems, Draper, Utah, USA) positioning a pair on 0 m, 10 m and 20 m; the faster run out of two runs within 5 minutes was used for calculations. Consecutively angle reproduction of shoulder, knee and hip joints was assessed bilaterally. Thereafter the simulated handball game was performed and heart rate (HR) was evaluated throughout the protocol using Polar® S625X (Polar Electro Oy, Kempele, Finland). Immediately after the simulated handball game POST measurements were performed, evaluating the following parameters: RPE, angle reproduction, 20 m sprints and weight. Measurements were carried out in the home stadium of the team and were performed on two separate days investigating 13 and 6 athletes, respectively.

The players did not exercise on the day before the study and on examination days. Furthermore the athletes were instructed not to eat and drink one hour before the start of the tests and during measurements. Measurements on both days were performed between 6 p.m. and 9 p.m, the time most handball games take place in the Austrian league.

We searched MEDLINE using "handball" as a search term and got 369 hits (March 2011). After reviewing the results we identified

Table 1: Characteristics of the simulated handball match and characteristics of participants. Abbreviations: BMI=body mass index, cm=centimeter, kg=kilogram, m=meter, min=minute, s=second.

Characteristics of the simulated handball match		
overall distance	4680 m	100.0%
walking (speed: <1.4m/s)	1620 m	34.6%
jogging (speed 3.0- 1.5m/s)	1440 m	30.8%
running (speed 5.2- 3.0m/s)	1260 m	26.9%
sprinting (>5.2m/s)	360m	7.7%
accelerations	81	
throws	9	
jumps	18	
ball contacts	180	
changes in direction	234	
changes in speed	225	
overall time	45min 27s	
Characteristics of participants		
	Mean±Standard Deviation	**Range**
Age	22.3 ± 4.9 years	16-38
Height	185 ± 5.4 cm	174-194
Weight	85.1 ± 11.3 kg	71.7-109.4
BMI	24.7 ± 2.9 kg/m²	20.9-29.4
Playing position	goalkeeper: 2 wing-player: 4 back-court: 7 circle runner: 5	
Arm dominance	right arm: 16 left arm: 2	

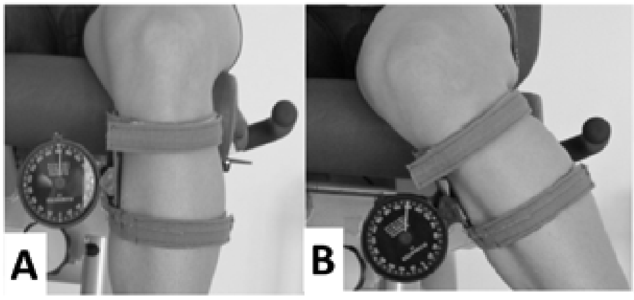

Figure 1: This figure illustrates the gravity inclinometer used to evaluate the angle reproduction. Panel A shows the hip in its neutral position. Panel B in a 30 degree inward rotation.

two publications (1,15) which characterized a professional male handball game. Furthermore textbooks for handball coaches were reviewed (18). All characteristics were combined to mimic an authentic handball game – a simulated handball game.

Athletes had to cover a distance of 20 m (i.e. the width of a handball field) in various speeds, i.e. 20 s, 10 s, 5 s and 4 s for 20 m. We prepared an audio file containing acoustic instructions concerning the running speed that was played continuously throughout the study. The order of the different elements was selected randomly. The tape had a length of 5 minutes and 3 seconds and was repeated 9 times resulting in a total time of 45 minutes and 27 seconds (Tab.1). Two ball contacts were performed whenever a slow run was performed. If the audio file ordered a fast run the athletes either had to jump as high as possible from a standing position or had to perform a throw while jumping.

The monitoring of the athlete's HR served to ensure an adequate exertion during the test episodes and furthermore their compliance was verified throughout the activities.

The Plurimeter® is a gravitation inclinometer first described by Rippstein in 1992 and assesses joint angles with an accuracy of ±2° (2,7). Its validity and reliability has been shown in several studies as well as the examination technique (2,5,7,23,25). The Plurimeter® was attached to the athlete's extremity using a hook and loop fastener (Fig.1). To examine shoulder, hip and knee joints, angles were adjusted at random by one examiner within the physiological range of motion of the investigated joint. After positioning the investigated joint in the initial position by the investigator, this position was held for three seconds by the blindfolded athlete without contact by the examiner, as described by Dover and co-workers (5). Thereafter the athletes returned their limb back into neutral position. The athlete was then asked to reproduce the angle as precise as possible. Shoulders were tested in 90° lateral elevation with a flexed forearm measuring internal and external rotation. Hips and knees were tested in a sitting position at a 90° flexion each. Hip movements were assessed using internal and external rotation, knee extensions were used to evaluate the JPS of knees. These procedures were done twice, for each joint separately. Twelve measurements per participant were achieved at PRE and POST. The arbitrary preadjusted angle and the reproduced angle were evaluated and the difference calculated. Then, mean values of both differences were calculated. We analyzed changes in all joints of one player (6 different joints), all knees (36 knees), all hips (36 hips) and all shoulders of all players (36 shoulders).

Statistical analysis was performed using PASW Statistics 18, Release Version 18.0.0 (SPSS, Inc. 2009, Chicago, IL, USA). Data is presented as mean and standard deviation. In addition, range is presented for the anthropometric data. A normality test was applied (Shapiro-Wilk test) and revealed normal distribution of our data. No power analysis was performed due to the fact that no previous study measured JPS changes due to fatigue in shoulders, knees and hips. However, we performed a post-hoc analysis (α-error: 0.05; β-error: 0.80; G*Power 3.1.7, Kiel, Germany) that resulted in a sample size of 44, 399 and 15 for shoulders, knees and hips, respectively. Effect size was determined with the standardized mean difference d with the 95% credible interval (95%-CI) and the Bayes-Factor (BF), according to Rouder et al. (17), using 50.000 resamples. Differences of data before and after the fatigue protocol were evaluated using paired t-tests (two tailed, 0.05 level of significance).

RESULTS

One athlete showed an inadequate compliance (HR mean 107±8 beats per minute [bpm]) and thus his data were excluded. Therefore eighteen professional male handball players were evaluated in our study (see Table 1).

The fatigue protocol showed an increase of HR throughout the fatigue protocol (from 139 to 153 bpm) with a mean HR of 144.5±16.2 bpm. The RPE on Borg's scale increased from 7±1 to 13±2 (p<0.001). The players' mean weight decreased from 85.1±11.3 to 84.2±11.1 kg resulting in a mean weight loss of 0.9±0.3 kg or 1.1±0.3 % of the body weight (p<0.001).

Table 2: Comparison of joint position sense deterioration PRE and POST the simulated handball game of shoulders and hips show significant deviation. Knees show no significant deterioration.

	PRE	POST	Δ	p-value
Shoulder	5.3±3.1°	8.8±4.9°	3.4°	0.023
Hip	2.8±2.1°	6.1±4.3°	3.2°	0.004
Knee	6.4±4.7°	7.3±3.5°	0.9°	0.561

Athletes needed 1.82±0.31 seconds (s) for the first 10 m and 1.53±0.29 s for the consecutive 10 m resulting in a mean overall sprinting time of 3.35±0.12 s at PRE. At POST sprinting times remained essentially unchanged: 1.83±0.31 s, 1.55±0.29 s and 3.36±0.12 s, respectively. No significant changes could be demonstrated for neither split time (0-10 m: p=0.87; 10-20 m: p=0.90) nor the total elapsed time (20 m: p=0.48).

The assessment of JPS of the shoulders resulted in a significant change (p=0.023; d=-0.55, 95%-CI= -1.05-0.07; BF=2.33±0%; see Table 2). Also JPS of the hips largely deteriorated (p=0.004; d=-0.75, 95%-CI=-1.28-0.23; BF=12.87±0.03%). JPS of the knees did not change (p=0.561; d=-0.13, 95%-CI=-0.58-0.31; BF=0.21±0%). No difference could be detected in JPS between the dominant and non-dominant shoulder (p=1.0).

DISCUSSION

In this study we were able to a) establish a simulated handball game to evaluate scientific questions that cannot be answered in a professional handball game; b) show a significant deterioration of JPS in hip and shoulder, but not in knee joints of male elite handball players.

We could demonstrate changes induced by our simulated handball game in RPE, HR and weight. All changes were significant and confirm previously published data on physiologic changes induced by handball. The decreased body weight of 1.1% is obviously due to sweating. The average HR of our participants showed a clear increase from the beginning of the protocol (139 bpm) to the end (153 bpm) with a mean of 144.5±16.2 bpm. Alexander and Boreskiev (1) report the mean HR of a world champion during a real handball game with 149 bpm, while that for a second skilled player it was 163.6 bpm. Lofin et al. (10) measured a mean HR of 156 bpm in 12 experienced handball players in a real handball game. Taken together, our HR was slightly lower than the HR measured in professional games in other studies. This difference can be attributed to the fact that a handball game induces not only physical but also psychological stress. In a study by Thorlund et al. the average HR was 165,3 bpm in a simulated handball game (20). These authors stated that their fatigue protocol was probably more intense than an actual handball game. Besides some minor variances between our simulated handball game and the previously published data (20), these results underline the usefulness of a simulated handball game to answer scientific questions in handball.

Various options are available to measure JPS. However, most instruments are not suitable to assess changes of acute fatigue because they are too time consuming. The gravity inclinometer Plurimeter® was precisely built to accurately measure joint movements (2,7). This device and similar devices have previously been used to perform angle reproduction tests in athletes (14,18). Angle reproduction tests are validated and reliable methods to detect acute fatigue induced e.g. in overhead throwing athletes in the shoulder (19).

In our study, local JPS deteriorated in shoulder and hip joints, whereas no changes could be shown in the knee joints of our athletes. These findings are consistent with other studies: Stillman et al. (19) were unable to detect changes in JPS in male elite athletes' knees following a leg fatigue protocol. Furthermore, Tripp et al. (22) confirmed changes in JPS of shoulder joints following an isolated fatigue protocol. To our knowledge no previous studies on JPS of hips are reported. However, the hip joint plays an important role in handball as the speed of side cuts is crucial in this game. To our knowledge we are the first to evaluate a comprehensive general fatigue protocol and its effects on local JPS in various joints and we therefore can only speculate on the potential underlying mechanism.

Myers and Lephart (12) discuss several theories how acute global fatigue may affect JPS. Muscle fatigue is believed to desensitize the muscle spindle threshold through changes in local metabolism (lactic acid, potassium chloride, bradykinin, arachidonic acid, and serotonin) (14). This in turn affects the local JPS and the neuromuscular responses, which are vital to local joint stability (11). We therefore speculate that this proposed mechanism predominantly affects shoulder and hip joints. These joints are mainly stabilized by muscles and are therefore more vulnerable to general fatigue induced destabilization. In the knee joint ligaments function as primary stabilization, therefore giving it more stability in a setting of muscular exhaustion.

Acute fatigue in shoulders induced via a submaximal throwing protocol results in a decreased ability to perform accurate throws as Tripp et al. (22) reported in 13 overhead-throwing athletes. However, it seems that this may be counteracted via differential and variable training. Wagner and Müller (24) report the results of a season long training intervention in an elite handball player to successfully improve throwing velocity, throwing accuracy and movement patterns. Forestier and Nougier (6) report major changes on movement pattern through muscular fatigue in overhead throws. As in untrained athletes our fatigue protocol would have likely induced an increase in sprinting times, we interpret the absence of change in 20 m sprint times as an indicator of a well developed sprint capacity in our participants. We hypothesize that likewise JPS changes can be minimized using such differential and variable training methods.

There are limitations to our study and the data must be interpreted in this context. First, we were unable to measure JPS in more joints due to the instrumentation used. As we assessed the effects of acute fatigue we had to rely on a measurement device that was able to quantify angle reproduction tests within minutes. The gravity inclinometer we used does not adequately assess angles e.g. in ankle joint and furthermore the effect of acute general fatigue is likely not to be detectable any more within a short time. Therefore we decided to measure and prioritize shoulder, hip and knee joints only. Second, our simulated handball game may have induced even more pronounced effects on JPS if the intensity would have been slightly higher. Also, we assessed only global fatigue using heart rate and rate of perceived exertion, the degree of the local load in joints was not assessed during our study. However, we assume that due to our study design the local load on joints was similar to a real handball match.

In conclusion the present study elucidates the impact of general fatigue on local joint position sense in various joints after a simulated handball game. The decreased potential in local angle reproduction in shoulder and hip joints may impair the accuracy in throwing and speed in side cuts and could thereby have a detrimental effect in a professional handball game. Further studies are warranted for a deeper understanding of the role of local joint position sense in the previously shown fatigue related decline of sporting abilities, also to develop training methods to counteract and possibly prevent fatigue related decline of abilities.

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