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The Acute Effect of Match-Play on Hip Isometric Strength and Flexibility in Female Field Hockey Players

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Abstract: The aim of this study was to determine the acute effect of simulated field hockey match-play on isometric knee flexion, adductor (ADD) and abductor (ABD) strength, adductor/abductor (ADD/ABD) strength ratio, countermovement jump height (CMJ), hip flexion and ankle dorsiflexion range of motion (ROM). Thirty competitive female field hockey players (23.0 ± 3.9 years old) participated in the study. Apart from the afore-mentioned variables, external (through GPS) and internal load (through RPE) were measured before (pre-match) and immediately after simulated hockey match-play (post-match) in both limbs. Isometric knee flexion strength (+7.0%, $p = 0.047$) and hip flexion ROM (+4.4%, $p = 0.022$) were higher post-match in the non-dominant limb, while CMJ values reduced (−11.33%, $p = 0.008$) when comparing from pre-match data. In addition, no differences were observed for isometric hip ADD, ABD, ADD/ABD strength ratio, passive hip flexion ROM and ankle dorsiflexion ROM test. A simulated field-hockey match produces an increment in hip isometric strength and hip flexion ROM values in the non-dominant limb and a decrease in jump height capacity. As a result, CMJ assessment should be considered post-match in order to identify players who would require further rest before returning to training.

Keywords: risk factors; performance; team sport; fatigue; groin; hamstring

1. Introduction

Field hockey is an intermittent sport where hockey players perform repeated actions such as changes of direction, dribbles, sprints, accelerations, decelerations and body impacts alternating high and moderate with low intensity efforts [1]. During an official field hockey match, consisting of four quarters of fifteen minutes each, hockey players cover around 6000–8000 m [2,3] primarily at low and medium intensities, with high-intensity efforts (>19 km/h^{-1}) making up around 6% of the total playing time [2]. Previous studies have reported an average of 14 to 48 injuries per 1000 h attributed to the high physical demands of this sport [4,5]. Specifically, most of these field hockey injuries have been reported in the lower limbs, especially in the thigh and groin [6], with the hamstring strain injury being the most frequent muscle injury (32%) [4], followed by the groin injury (10%) [6]. Consequently, identification of the risk factors associated with groin and/or hamstring injury occurrence is essential.

In this sense, previous studies in different intermittent sports such as football [7], tennis [8] and ice hockey [9], have identified several modifiable intrinsic risk factors as causing an increased likelihood of developing groin and hamstring injuries. Among them, a weakness in the isometric adductor strength (ADD) [7,10] and lower adduction/abduction strength ratio (ADD/ABD) [9] have been associated with a higher risk of sustained groin injuries, while a lower hamstring strength [11–13], decreased range of hip flexion [14] and ankle dorsiflexion range of motion (ROM) have been associated with hamstring strain injuries [15]. However, some conflicting results have been found in literature regarding these factors [16–18]. Notably, most researches have investigated these risk factors before the commencement of the season or in off-season situations [19]. However, the ability to capture fluctuations in ROM and/or strength profile in-season, specifically in response to match-play, has not been studied [19].

Similar to other intermittent sports, field hockey players reported a higher incidence of injuries during matches compared to training [6] probably due to the higher intensity reported in matches versus training, and the appearance of fatigue [20,21]. It is well known that there is a decrement of lower limbs' power performance after match-play, and this measure is one of the potential factors in injury causation in intermittent sport [22]. Appearance of fatigue is known to reduce sports performance through reduced muscle strength, neuromuscular control and ROM [22]. In this line, the impact of match-play on ADD, ABD, hamstring strength and ROM during hip flexion and ankle dorsiflexion has been studied recently in several sports such as tennis, football and basketball [19,23–25]; however, to the best of the authors' knowledge, there is no information regarding this effect in field hockey. Therefore, the aim of this study was to examine the acute effect of hockey match-play on several risk factors such as isometric knee flexion and hip ADD and ABD strength, ADD/ABD strength ratio, passive hip flexion ROM and ankle dorsiflexion ROM and countermovement jump (CMJ) in elite female hockey players.

2. Materials and Methods

2.1. Subjects

Thirty highly competitive female hockey players (age, 23.0 ± 3.9 years; body mass, 60.0 ± 7.5 kg; height, 1.60 ± 0.09 m; body mass index, 22.0 ± 2.1 kg·m^2; hours per week, 9.4 ± 4.4; playing experience, 14.3 ± 4.9 years) volunteered to participate in this investigation. The players were recruited from two different professional teams. The inclusion criteria were: (a) To be healthy and able to complete a full game of field hockey; (b) to be uninjured and declared match-fit by the medical and coaching staff at the time of the experiment and not to have taken any type of medication to treat pain or musculoskeletal injuries at the time of the study; and (c) to have an absence of late onset muscle pain during the training session [26]. All players were informed of the tests they were to perform and signed the consent form. The experimental procedure of this study was conducted in accordance with the Declaration of Helsinki and the approval by the Ethics Committee of the University Francisco de Vitoria, number 45/2018.

2.2. Experimental Protocol

Following their arrival, female hockey players filled out a questionnaire which included personal information such as body mass, height, medical history, training frequency and experience (practice hours per week and playing experience in field hockey). Testing (i.e., ROM, isometric strength, and countermovement jump) was performed in the clinical area of each field hockey club. Testing was conducted by two sports physiotherapists: a senior physiotherapist with over nineteen years of experience and a junior physiotherapist with two years of experience, to ensure participants' positioning during measurements. Considering recommendations by Wollin, Thorborg and Pizzari [19], the testing order of the players and the selection of the leg tested were randomly chosen prior to the pre-match test. Pre-match testing was performed 60 min prior to match-play, and the post-match re-testing was performed immediately after the match. At the beginning of the pre-match testing, participants carried out a standardized warm-up that consisted of 5 min of jogging at 10 km·h^{-1} and 5 min of static stretches and joint mobility exercises [27]. Subsequently, participants played the simulated field hockey match according to the International Hockey Federation rules on a rectangular surface, 91.40 m long and 55.00 m wide. The external load of the simulated matches were estimated using a global positioning system (GPS) (Wimu ProTM, RealTrack Systems, Spain) placed in specific vests worn by the players, these devices operated at a sampling frequency of 10 Hz and its validity and reliability have been reported previously [28]. In addition, subjective internal load of the game was obtained using the modified RPE scale (i.e., 0–10 points) within 30 min of match termination [29]. The following variables were used to assess the external load during match-play, total distance covered per minute at different velocities ranges during a 60 min match as previously reported [3]. To reduce the interference of uncontrolled variables, all subjects were instructed to maintain their habitual lifestyle and normal dietary intake before and during the study, and refrain from caffeine ingestion 24 h before the experiment [30].

2.3. Isometric Strength of Abductors (ABD) Adductors (ADD) and Knee Flexion

Hip isometric ADD and ABD strength were measured according to the methodology previously reported [31] using a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA). Participants were placed in a supine position with their hips in a neutral position and told to stabilize themselves by holding onto the sides of the table. Examiner 1 applied a resistance on a fixed position (ABD: At 5 cm proximal to the lateral malleolus; ADD: At 5 cm proximal to the medial malleolus). The hockey players were instructed to exert a voluntary contraction for a maximum of 5 s against the dynamometer [31]. Two attempts were registered for each contraction of each limb and a 30 s rest period between attempts. Regarding the isometric knee flexion, the strength test was evaluated by placing the subject in the prone position, with 15 degrees of knee flexion and with their hips in a neutral position [32]. Examiner 1 placed the dynamometer on the distal portion of the sural triceps, three centimeters above the bimalleolar line. Examiner 2 clamped the subject's pelvis over the sacrum, to prevent elevation during the test. Examiner 1 requested the participant to flex their knee with the intention of bringing the heel of the foot to the gluteus. Similarly, two repetitions were recorded for each limb with a 30 s rest between attempts. Isometric hip ADD, ABD and knee flexion strength was expressed as the maximal hip and knee torque per kilogram of body weight (Nm·kg^{-1}) using the external lever arm and body weight of each participant. The mean value out of two attempts was recorded and selected for further analysis.

2.4. Ankle Dorsiflexion ROM

Unilateral ankle dorsiflexion ROM was measured with LegMotion System (LegMotion, Check your Motion, Albacete, Spain). The testing was carried out following the methodology previously described by Calatayud et al. [33]; participants were in a standing position on the LegMotion System with the tested foot on the measurement platform and the contralateral foot out of the platform with the toes at the edge of it. Each player performed the test with their hands on the hips and the assigned foot in the middle of the longitudinal line behind the transversal line of the platform. From this position, subjects were instructed to flex the knee forwards, placing it in contact with the metal stick. When the subject was able to maintain heel and knee contact, the metal stick was progressively moved away from the knee, and the following achieved distance was recorded. Two attempts were allowed for each limb (i.e., left and right), with 15 s of passive recovery between trials. The mean value of the two attempts was selected for further analysis.

2.5. Hip Flexion ROM

Passive hip flexion ROM values with the knee extended were evaluated with the Straight Leg Elevation Test (SLET). Participants made two maximum passive attempts for the dominant and non-dominant leg, when the difference between one attempt and another was greater than 5%, a third attempt was made, selecting the mean value of the two attempts whose results were similar for further statistical analysis [34]. A unilevel inclinometer ISOMED (Portland, OR, USA) with a telescopic was used for the measurement. The test ended with one or more of the following criteria: (a) The examiner was unable to continue the joint movement evaluated due to the high resistance developed by the stretched muscle group; (b) The participant reported an important sensation of discomfort; or (c) The examiners noted compensations that could increase the ROM [35]. The inclinometer was placed approximately on the external malleolus and the distal arm was aligned parallel to an imaginary bisecting line of the extremity [35]. The mean value out of two attempts was recorded and selected for further analysis.

2.6. Countermovement Jump (CMJ)

Participants carried out three repetitions of CMJ using a contact mat jump system (Chronojump Boscosystem, Barcelona, Spain) with their arms on hips [36]. They were instructed to jump and land in the same place, with the body in an erect position during the jump until landing. Each participant performed two maximal CMJs interspersed with 45 s of passive recovery. In addition, the mean value out of two attempts was recorded and selected for further analysis.

2.7. Statistical Analysis

Data were calculated as means/standard deviation. The Shapiro–Wilk test was selected to assess the normal distribution. All study variables were compared using a *t* test (pre- vs. post-match). The statistical significance level was set at $p < 0.05$. Cohen's effect sizes were calculated and presented with their respective 95% confidence intervals (C.I.) based on the following criteria: Trivial effect (0–0.19), small effect (0.20–0.49), medium effect (0.50–0.79) and large effect (0.80 and greater) [37]. All the statistical analyses were completed using the SPSS software version 25 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Match-Play Workload

The internal match-play workload was 6.83 ± 0.80 units (RPE). In addition, female hockey players covered a mean distance of 5456.50 ± 699.09 m across different velocity profiles (Table 1).

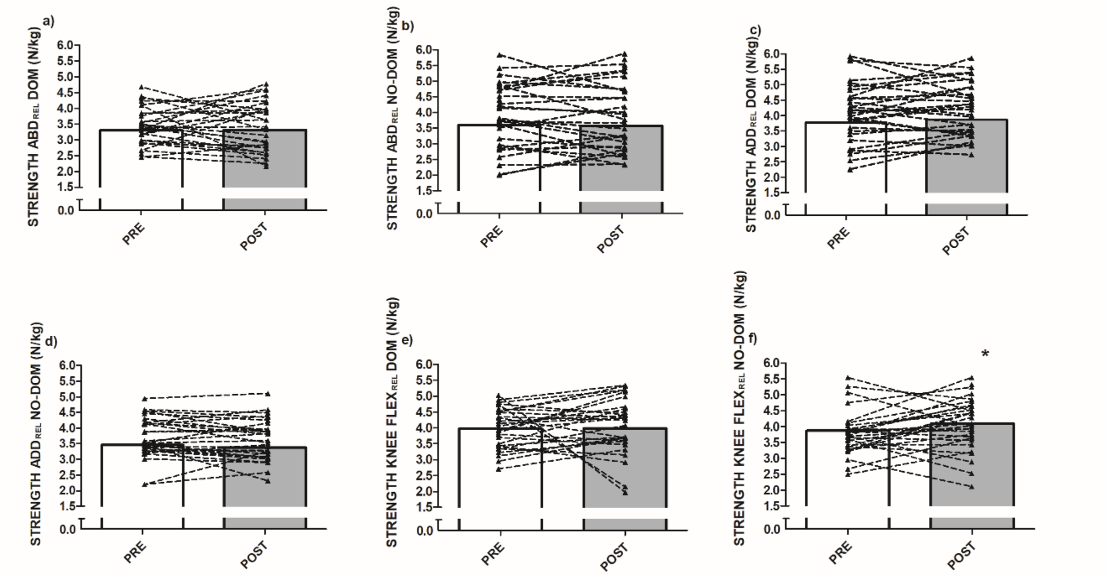
Table 1. Mean distances and % of total distance covered during the match at different velocity ranges.

Velocity Range	Distance Covered (m)	Total Distance (%)
0.0–6.0 km·h^{-1}	2692.04 ± 614.70	49.36 ± 9.71
6.1–12.0 km·h^{-1}	1781.15 ± 380.97	32.47 ± 4.53
12.1–18.0 km·h^{-1}	851.66 ± 282.16	15.74 ± 5.48
18.1–21.0 km·h^{-1}	107.59 ± 75.87	1.98 ± 1.40
21.1–24.0 km·h^{-1}	21.59 ± 23.66	0.40 ± 0.44
>24.1 km·h^{-1}	2.47 ± 6.19	0.05 ± 0.12

Abbreviations: km·h^{-1} = kilometers/hour; m = meters.

3.2. Isometric Strength and Countermovement Jump

No statistical differences were seen in relative isometric hip ABD strength in the dominant (+2.42%, $p = 0.864$, ES [C.I.] = 0.01 [−0.08, 0.11]) (Figure 1a) and non-dominant limb (−1.46%, $p = 0.834$, ES [C.I.] = −0.02 [−0.12, 0.07]) (Figure 1b); nor in the relative isometric hip ADD strength in the dominant(−2.10%, $p = 0.399$, ES [C.I.] = 0.10 [0.00, 0.19]) (Figure 1c) and non-dominant limb (+3.38%, $p = 0.349$, ES [C.I.] = 0.11 [0.02, 0.21]) (Figure 1d). In addition, no differences were obtained in ADD/ABD strength ratios in dominant (1.14 vs. 1.19, $p = 0.220$, ES [C.I.] = 0.28 [0.19–0.37]) and non-dominant limbs (0.98 vs. 0.96, p = 0.600, ES [C.I.] = 0.14 [0.05–0.24]) when comparing them pre and post-match. However, for isometric knee flexion strength, statistical differences were obtained in the non-dominant limb (7.0%, p = 0.047; ES [C.I.] = 0.29 [0.20, 0.38]) (Figure 1f) but no differences were reported in the dominant limb (0.1%, p = 0.983; ES [C.I.] = 0.11 [0.02, 0.21]) (Figure 1f). Finally, neuromuscular fatigue was measured by a countermovement jump test after match-play (23.0 ± 4.9 vs. 20.5 ± 6.6 cm, p = 0.008, ES [C.I.] = 0.44 [0.34, 0.53]).



Abbreviations: DOM = dominant; NO-DOM = non-dominant; ADD = Adductor; ABD = Abductor; FLEX = flexion; REL = relative. * Significant differences compared to the PRE values at p < 0.05.

Figure 1. Hip and knee isometric hip abduction (ABD), adduction (ADD) and knee flexion strength values. (**a**) Relative isometric hip ABD strength in the dominant limb; (**b**) relative hip abductor strength in the non-dominant limb; (**c**) relative hip adductor strength in the dominant limb; (**d**) relative hip adductor strength in the non-dominant limb; (**e**) relative knee flexion strength in the dominant limb; (**f**) relative knee flexion strength in the non-dominant limb.

3.3. Hip Flexion and Ankle ROM

A significant increase was found when comparing the ROM in the hip flexion (straight leg elevation raise test) for the non-dominant limb (+4.38% p = 0.022). However, no differences were found in the dominant limb (+1.19%, p = 0.753) (Table 2). In addition, no differences were obtained for ankle dorsiflexion ROM values after field hockey match in the dominant limb (−3.77%; p = 0.316) and non-dominant limb (−2.34%; p = 0.362) (Table 2).

Table 2. Hip and ankle range of motion (ROM).

Variables	Pre-Match	Post-Match	*p*-Value	ES [95%CI]
Straight Leg Elevation Test DOM (°)	81.1 ± 12.3	82 0 ± 9.1	0.753	0.09 [0.00–0.18]
Straight Leg Elevation Test NO-DOM (°)	81.4 ± 10.3	84.9 ± 9.9	0.022 *	0.35 [0.26–0.45]
Ankle dorsiflexion DOM (cm)	10.9 ± 2.5	10.4 ± 2.7	0.316	0.16 [0.06–0.25]
Ankle dorsiflexion NO-DOM (cm)	11.1 ± 2.7	10.8 ± 2.7	0.362	0.10 [0.00–0.19]

Abbreviations: DOM = dominant-side; NO-DOM = non-dominant side; ° = degrees; cm = centimeters; * Significant differences compared to the PRE values at $p < 0.05$.

4. Discussion

The aim of this study was to determine the acute effect of hockey match-play on several risk factors such as isometric knee flexion, hip ADD and ABD strength, ADD/ABD strength ratio, passive hip flexion ROM, ankle dorsiflexion ROM and CMJ in competitive female hockey players. To the best of the authors' knowledge, this is the first study that analyzed the acute effects of hockey match-play on several risk factors in female athletes. The main results showed that hockey match-play acutely produced a decrease in CMJ performance, and an increase in isometric knee flexion strength and hip flexion ROM with knee extension in the non-dominant limb. However, no significant differences were found in isometric hip ADD, ABD strength and ADD/ABD strength ratio and ankle dorsiflexion ROM in both limbs.

The CMJ is one of the most important tests used to evaluate the lower-limb muscles fatigue [38,39]. The results in this study showed a significant reduction in levels of performance in CMJ (−11.33%) after match-play which was in agreement with previous studies conducted in other intermittent sports [40,41]. Recent research from Kim and Kipp [42] has shown that the gastrocnemius, soleus and vastus muscles have the largest contribution to vertical center of mass (COM) acceleration during the CMJ, and the soleus and gastrocnemius muscles function closest to their maximal capacities. If one were to look at the distances covered by the players (Table 1), one can observe that most of the distance had been covered at lower intensities. Here, the production of the horizontal force has been attributed to the muscles of the lower limb: namely tibialis anterior, gastrocnemius and soleus [2]. This indicates that a greater fatigue caused by distances ran at these intensities appears to have increased the neuromuscular fatigue associated with the CMJ, leading to a decrease in performance. In addition, albeit speculative, another possible reason for the decrease values in the CMJ test after match-play has been attributed to disruptions within the muscular fibers [41], increasing some markers of muscle damage (e.g., creatine-kinase, myoglobin) after a match in intermittent sports [41,43]. Moreover, previous literature described the inflammatory responses and fibrillar damage to the muscles and showed a decrease in metabolic indices in athletes after playing a match; however, this speculation requires further investigation.

Muscle strength in the lower limbs is essential to produce explosive actions in hockey (e.g., accelerations, changes of direction). The results obtained in the present study showed improvements in the isometric knee flexion strength (+7.0%) immediately post-match in the non-dominant limb. While no previous study has reported knee flexion strength values in field hockey players, these results differ from previous studies conducted in other intermittent sports, which revealed a lower knee flexion strength post-match-play [19,44]. The lack of agreement between studies could be related to the different match-play demands of the participants (e.g., total distance covered, duration of match, etc.). While in the current study hockey players reported an average of 5456.50 ± 699.09 m total distance covered and 21.59 ± 23.66 m at high speeds over 21 $km{\cdot}h^{-1}$, previous studies in female soccer players showed they covered distances over 10,000 m during a match (90 min duration), of which at least 600 m were at high speed running intensities [45]. The current results suggest that the effect provoked by field-hockey match-play did not decrease the isometric knee flexion strength in the dominant limb, which has been related to a higher hamstring injury risk in previous studies [46,47]. The absence of changes in the isometric knee flexion strength can be attributed to the lower distances covered at high running speeds. Extensive research [47] has shown that the hamstring muscles are most active in this phase, when their function is to increase stride frequency and produce a greater horizontal force as the contact time reduces. Given the distances covered in the different zones, it can be assumed that the hamstring muscles are not fatigued as in sports such as soccer, where a greater distance is covered at these intensities.

A reduced ROM during the straight leg raise test and dorsiflexion of the ankle ROM has been linked to the risk of hamstring injury [14,15]. Present results have shown an increase in the straight leg raise ROM levels for the non-dominant limb (+5.81%) and no significant differences in the dominant limb. No differences were seen for the ankle dorsiflexion ROM either for both legs after match-play. To the best of the authors' knowledge, only Wollin et al. (2017) analyzed the straight leg raise ROM after match-play on intermittent sports and report no significant differences after match-play [19]. Concerning ankle dorsiflexion ROM, some previous studies conducted in football [24], basketball [25] and Australian-rules football [44] showed different results. While Charlton et al. [44] reported reductions in ankle dorsiflexion ROM immediately after an Australian-rules football match, Wollin et al. [19] showed non-significant decrements in football players, and finally Moreno-Pérez et al. [24,25] in football and basketball observed increased ROM values post-match from pre-match in dominant and non-dominant limbs. While these sports involve the same multidirectional movements (e.g., accelerations, decelerations, changes of direction) during practice, they cannot be compared due to the differences in the characteristics of the sport; for example, the total duration is less in field hockey than other intermittent sports. Thus, increases in hip flexion ROM immediately post-match are likely due to the increase in tissue extensibility induced by temperature increment which leads to a reduction of the viscous resistance of muscle tissues and joints [48,49]. However, this is a speculation that needs to be elucidated in future studies.

As far as isometric hip ADD and ABD strength values and ADD/ABD strength ratio go, the results showed no significant differences between post-match from pre-match. While is difficult to establish comparisons, as no previous study has reported isometric hip ADD and ABD strength values in hockey players, the findings of the current study were similar to those of a previous study [50] conducted with 14 rugby players. However, the present results disagree with the results reported by a previous study in tennis players [23]. This lack of agreement between studies may be due to differences in physical demands and tactical aspects between the sports. In tennis, players are required to perform repetitive short high-intensity movements, which impose an elevated concentric and eccentric load on the ADD muscles, while hockey players perform multiple different movements at several intensities. One must also consider that hockey, like in rugby, permits rolling substitutions.

This study contains limitations that require acknowledgment. Firstly, as the current study was conducted with a specific sample of female field hockey players, conducted during a simulated match, the characteristics of the players do not permit a generalization of the results found. In addition, the selected measures in this study in response to hockey match-play were performed immediately post-match; future studies should evaluate these variables using several time-points to understand the recovery fatigue induces, for example registering data 48 h after the match. This study looked at the effect following a single simulated match; more data collected over a series of official matches, or even, over an entire season could provide more conclusive results about the effects of match-play on these potential risk factors.

5. Conclusions

A simulated field-hockey match increases hip isometric flexion strength and hip flexion ROM in the non-dominant limb and decreases jump height capacity. However, no differences were reported in isometric ADD and ABD strength and ADD/ABD strength ratio in the dominant and non-dominant limb, or in dominant hip flexion and ankle dorsiflexion ROM values between the pre- and post-match examinations. Finally, female hockey players who present a decrease in jump height capacity, may require additional rest between training and competitions.

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