




## Article

# Effects of Consecutive Matches on Isometric Hamstring Strength, Flexibility Values and Neuromuscular Performance in Female Field Hockey Players. A Prospective, Observational Study

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**Citation:** Sánchez-Migallón, V.; Moreno-Pérez, V.; López-Samanes, A.; Fernández-Ruiz, V.; Gaos, S.; Díaz-Maroto, J.B.; van den Tillaar, R.; Navandar, A. Effects of Consecutive Matches on Isometric Hamstring Strength, Flexibility Values and Neuromuscular Performance in Female Field Hockey Players. A Prospective, Observational Study. *Appl. Sci.* **2021**, *11*, 8938. <https://doi.org/10.3390/app11198938>

Academic Editors: Alejandro San Juan Ferrer and Cheng-Kung Cheng

Received: 31 July 2021  
Accepted: 21 September 2021  
Published: 25 September 2021

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**Abstract:** This study aimed to analyze the effects of match congestion in a short period on isometric hamstring strength and hip/ankle range of motion in female field hockey players. Fourteen professional female field hockey players (age:  $20.0 \pm 5.4$  years) played two consecutive hockey matches in 24 h and maximal isometric hamstring strength and hip and ankle range of motion were obtained before and after the first match, after the second match, and 48 h after the second match. Furthermore, locomotion patterns and ratings of perceived exertion were recorded during hockey competitions. Isometric knee flexion strength showed significantly higher values 48 h after the second match for the non-dominant limb ( $p \leq 0.005$ ,  $\eta^2 = 0.19$ ), while no differences were reported in the dominant limb ( $p = 0.370$ ,  $\eta^2 = 0.05$ ). In addition, no differences were reported in the range-of-motion (ROM) variables such as the straight leg raise test or ankle dorsiflexion test ( $p = 0.075$ – $0.217$ ,  $\eta^2 = 0.01$ – $0.03$ ). The countermovement jump height steadily increased over the matches except between post-match 2 and 48 h after post-match 2 ( $p < 0.001$ ,  $\eta^2 = 0.382$ ). Two consecutive official league field hockey matches played within 24 h did not have a negative effect on lower-limb risk factors (strength, hip and ankle ranges of motion, and ratings of perceived exertion) in female field hockey players directly, but they improved 48 h after the matches. This could indicate that 48 h recovery period following matches might be ideal for female field hockey players.

**Keywords:** team sport; hamstrings; fatigue; fixture congestion; countermovement jump; flexibility

## 1. Introduction

Field hockey is an intermittent sport characterized by high-intensity bouts interspersed with moderate to low periods combined with continuous accelerations, decelerations, and changes in direction [1]. During a field hockey match, female players approximately cover between 5300 and 6800 m [2,3] over a sixty minutes period of which around 20% is covered at high speeds [2,4].

During official field hockey competitions, teams often play two consecutive games in less than twenty-four hours. This imposes high physical demands on an athlete, limiting physical performance in subsequent matches due to an insufficient recovery [5]. In other intermittent team sports such as soccer, research has shown that the demands of a single

match can induce muscle damage and post-match fatigue that can last up to seventy-two hours [6]. This has resulted in a reduction in the ability to maintain high speeds and in the number of accelerations/minute [7], being attributed to peripheral fatigue appearance due to depletions in muscle glycogen concentrations [8]. As a result, limited recovery time between matches increases residual fatigue and consequently increases the risk of injury [9], as evidenced by epidemiological research. Research has shown higher injury rates in competitions where there were four or fewer days of recovery when compared to competitions with six or more days of recovery [10].

Furthermore, epidemiological research has shown that the lower limbs are the most affected by injuries in field hockey, with the hamstring strain injury being one of the most frequent muscle injuries [11]. Hamstring injuries are common in other intermittent sports, occurring during maximal or sub-maximal sprinting [12] when there is constant, repetitive stress placed on these muscles when the fibers are rapidly lengthened and contracted during the sprint cycle [13]. Since previous research in similar intermittent sports has shown that the incidence of such injuries is higher during matches [14], playing consecutive games with insufficient recovery can not only affect physical performance but can also increase the injury risk. To implement preventive strategies, the identification of risk factors, both intrinsic and extrinsic, associated with hamstring injury occurrence is crucial. These include: age [15], previous injury [16], hamstring strength [17–19], decreased range of knee extension [20,21], and ankle dorsiflexion [22,23]. Specifically, in the case of an intermittent sport such as field hockey, fatigue has been linked to a decrease in hamstring strength values, and this is an important risk factor for a hamstring injury [24]. Moreover, an incomplete recovery could lead to lower strength values in the hamstrings [25]. Despite the relevance of cumulative fatigue on the hamstring musculoskeletal characteristics of athletes, the effect of consecutive matches on hamstring injury risk factors has not yet been examined in field hockey players during the accumulation of several matches. Therefore, this study aimed to examine the effects of two consecutive official league field hockey matches, played within 24 h, on lower-limb risk factors of hamstring injuries such as isometric knee flexion strength, passive hip flexion [21], and ankle dorsiflexion range of motion [26]. Based on previous research, it was hypothesized that the registered values for these variables will reduce over the duration of the matches and recover partially 48 h after the 2nd match.

## 2. Materials and Methods

### 2.1. Participants

Fourteen semiprofessional female field hockey players (age:  $20.0 \pm 5.4$  years (range: 15–28 years); weight:  $60.7 \pm 7.2$  kg; height:  $1.67 \pm 0.1$  m, years of experience:  $11.0 \pm 6.0$  years; weekly training time:  $6.3 \pm 0.8$  h) volunteered to participate in the study. The participants belonged to a club that played in the second division hockey league in Spain. Players were included in the study if they had the clearance of the medical and technical staff to complete a full match of field hockey, not having sustained a medically diagnosed, serious injury (layoff > 3 weeks) in the last six months prior to the study, and not having taken any type of medication to treat pain or musculoskeletal injuries at the time of the study. All players were informed of the study they were to conduct, informed of the tests that they were to undertake, and signed informed consents. Participants were excluded if they sustained an injury during the matches and could not complete the tests. The experimental procedure of this study was in accordance with the guidelines stated in the Declaration of Helsinki and was approved by the Ethics Committee of Universidad Francisco de Vitoria (number 45/2018).

### 2.2. Experimental Design

The required sample size was determined by statistical power calculation on the basis of previous studies [25]. The minimum number of participants required to detect a difference in isometric hamstring strength performance between two groups, with a

power of 1.20 and two-tailed level set at 0.05, was estimated as six per group using the GPower statistical program (v. 3.6.1) [27]. A prospective, descriptive study (Figure 1) was carried where players were tested in four moments: sixty minutes before the first match (pre-match 1), immediately after the first match (post-match 1), immediately after the second match (post-match 2), and 48 h after the conclusion of the second match (48 h post-match 2).

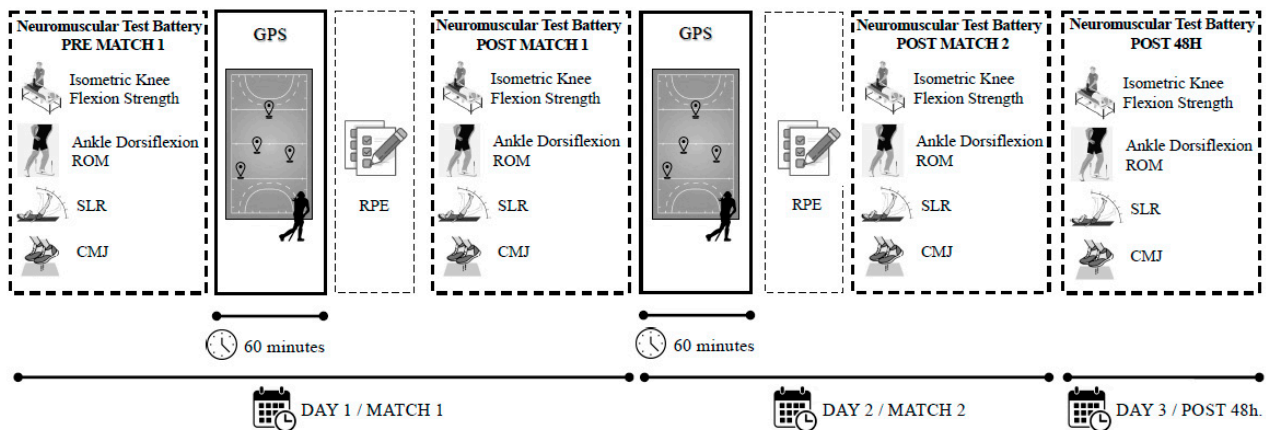


Figure 1. The experimental protocol used in the study.

### 2.3. Experimental Protocol

One week before the onset of the experiments, a familiarization session that included the execution of all tests was carried out by participants and anthropometric data, age, medical history, training frequency, and years of experience were collected. On the experimental days, participants arrived at field hockey facilities for each evaluation session. On the first day, participants performed a standardized warm-up consisting of continuous running for 2 min, dynamic joint mobility for 2 min, and specific exercises such as squats and forward lunges for 1 min. The participants then underwent the neuromuscular test battery consisting of isometric knee flexion strength, hip flexion range of motion (ROM) with the knee extended with the straight leg raise test (SLR), ankle dorsiflexion ROM, and countermovement jump (CMJ). The order of the tests and the selection of players were randomly determined before the measurements [28]. All tests were conducted by three physiotherapists with over five years of experience. During the matches, the players carried a portable GPS device with a built-in accelerometer in a customized vest from which the external load was measured. Therefore, thirty minutes after the end of each hockey match, female participants reported RPE values [29]. Between the different matches, hockey players ingested the same meals, slept at least 7 h, and were advised not to drink caffeine or energy drinks to avoid the influence of circadian rhythms on caffeine ingestion [30]. During the 48 h after the second match, they were advised not to exert exhausting efforts.

#### 2.3.1. Isometric Knee Flexion Strength

The isometric knee flexion strength of either limb was measured using a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA). The hamstring strength test was evaluated by positioning the subject from the prone position, with 15 degrees of knee flexion [31]. One examiner placed the dynamometer in the distal portion of the triceps surae, three centimeters above the bimalleolar line, while another placed their palm over the participant's sacrum, to prevent elevation during the test. The first examiner requested the player to flex their knee to bring the heel of the foot to the glutes. The players performed voluntary contractions for a maximum of five seconds against the dynamometer and repeated the exercise twice for each leg. There was a rest period of thirty seconds between each measurement [28,32]. Two repetitions were performed for both dominant and non-dominant legs, and the highest

recorded measurement was considered for further analysis. This value was normalized based on the body mass of the participant.

### 2.3.2. Ankle Dorsiflexion ROM

The ankle dorsiflexion ROM was performed on both ankles following the protocol of Calatayud et al. [33] using the leg-motion system test (LegMotion, Check your Motion, Albacete, Spain). Participants were in a standing position in the leg-motion system with the foot to be measured on the measurement scale. The contralateral foot was placed outside the platform with the toes on its edge. Each player performed the test with their hands on their hips, with the assigned foot in the middle of the longitudinal line, and just behind the transverse line of the platform. While maintaining this position, the subjects were instructed to flex their knees, causing it to move forward to contact the metal stick. When the participant was able to maintain ground contact with their heel, and take the knee to the maximum distance, the metal rod moved away from the knee, and the next distance reached was recorded [33,34]. Two repetitions were performed on each leg, with 10 s of passive recovery between each test, and the highest score between these measurements was chosen for further analysis.

### 2.3.3. Straight Leg Raise Test

The SLR test was used to measure the flexibility of the hamstring muscles [35]. An ISOMED (Portland, OR, USA) unilevel inclinometer with a telescopic extension rod was used for the measurement. The inclinometer was placed approximately on the external malleolus, and the distal arm was aligned parallel to an imaginary bisecting line of the limb. The test ended when one or more of the following criteria were met [36]: (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 a significant sense of discomfort or appearance of pain; (c) the examiners noted compensations that could increase the score. Two repetitions were performed for both the dominant and non-dominant leg, and the highest recorded measurement was considered for further analysis.

### 2.3.4. Vertical Jump with Countermovement Test (CMJ)

The CMJ test was performed bilaterally to evaluate the neuromuscular fatigue accumulated [37]. On command, participants flexed their knees at 90° and jumped as high as possible while maintaining their hands on their hips and were instructed to jump and land in the same place, with the body in an upright position and legs extended during the jump until landing [38]. The Chronojump Boscosystem (Barcelona, Spain) contact platform [39] was used to measure the vertical jump height during CMJ. Participants completed two repetitions of a CMJ interspersed with 45 s of passive recovery, and the highest recorded measurement was considered for further analysis.

### 2.3.5. Global Positioning System and Accelerometer Device (GPS)

To determine the physical demands, all players were equipped with a 10 Hz portable GPS (Viper pod 2, STATSports, Belfast, Northern Ireland), which was attached to a lycra vest between the shoulders. Each field player carried individual units during matches and used the same unit in both matches to reduce measurement error [40]. The duration and frequency of movement activities were quantified with respect to the percentage of time and meters traveled by the players based on six activity zones bounded by various speeds [41]: walking (0–6.0 km/h); low-intensity running (6.1–12.0 km/h); medium-intensity running (12.1–14.0 km/h); high-intensity running (14.1–18.0 km/h); very high-intensity running (18.1–25.0 km/h); sprinting (>25.1 km/h). Except for the total distance, all variables analyzed were relativized per minute of match play.

### 2.3.6. Internal Match Load (RPE)

The intensity of all matches was determined using Borg CR-10's modified scale of perceived effort rate (RPE); each player provided a score 30 min after the end of the match [1].

### 2.4. Statistical Analysis

The means and standard deviations of the performance and test variables were determined. The measures of external load and internal load were compared between the two matches using a paired samples *t*-test.

For the data analysis of the test variables registered at the four different moments, pre-match 1, post-match 1, post-match 2, and 48 h post-match 2, a repeated-measures analysis of variance (ANOVA) was used to determine differences in the measures across the four instances. If significant differences were found, a Bonferroni post hoc test was performed. In cases where the sphericity assumption was violated, a Greenhouse–Geisser adjustment for *p*-values was reported. The effect sizes of the repeated measures ANOVA were measured using partial  $\eta_p^2$  values, and the following thresholds were used: trivial ( $\eta_p^2 \leq 0.01$ ); small ( $0.01 < \eta_p^2 \leq 0.06$ ); medium ( $0.06 < \eta_p^2 \leq 0.14$ ); large ( $\eta_p^2 > 0.14$ ) [42]. Differences between GPS registered-running variables across the two consecutive matches were tested with a paired samples *t*-test, and effect sizes were determined using Cohen's *d* [43]. These were then converted to partial eta squared values based on the equations presented by Cohen and the thresholds mentioned earlier. Significance was set at  $p < 0.05$ . The statistical analysis was carried out using Jamovi (version 1.8.1, [43]).

## 3. Results

The variables registered from the GPS showed a significant increase in the total distance covered between matches one and two ( $6589.0 \pm 2372.27$  m vs.  $7439.80 \pm 2177.96$  m;  $p = 0.040$ ;  $\eta_p^2 = 0.092$ ), but no significant differences were obtained for the distance run at different intensities or between the RPE values registered after the matches either (Table 1).

**Table 1.** Difference between GPS measured variables across the two matches.

Variable	Match 1	Match 2	<i>p</i>	$\eta_p^2$
Relative walking distance [0–6.0 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	68.84 ± 38.63	75.21 ± 21.40	0.522	0.009
Relative low-intensity running distance [6.1–12.0 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	51.94 ± 28.10	48.10 ± 14.21	0.498	0.010
Relative medium-intensity running distance [12.1–14.0 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	11.74 ± 4.99	12.09 ± 4.36	0.877	0.001
Relative high-intensity running distance [14.1–18.0 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	12.90 ± 7.96	14.13 ± 6.01	0.564	0.007
Relative very high-intensity running distance [18.1–25.0 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	3.81 ± 3.43	3.94 ± 2.19	0.670	0.004
Relative sprinting distance [>25 km·h <sup>-1</sup> ] (m·min <sup>-1</sup> )	0.17 ± 0.48	0.01 ± 0.02	0.331	0.027
Session RPE (AU)	346.18 ± 231.73	392.31 ± 203.82	0.170	0.061

Abbreviations: km·h<sup>-1</sup> = kilometers/hour; m = meters; AU: arbitrary units.

The isometric knee flexion strength (Figure 2) showed significant differences for the non-dominant limb ( $F_{(1.43,15.70)} = 10.60$ ,  $p = 0.003$ ,  $\eta_p^2 = 0.198$ ) and the post hoc tests showed that 48 h post-match 2 values were significantly higher than in all other tests ( $p \leq 0.005$ ). In the dominant limb, no significant differences were found ( $F_{(1.13,12.47)} = 1.08$ ,  $p = 0.370$ ,  $\eta_p^2 = 0.052$ ).

Considering the ROM variables (Figure 3), the SLR test showed no differences in the dominant ( $F_{(3,33)} = 1.56$ ,  $p = 0.217$ ,  $\eta_p^2 = 0.031$ ) or non-dominant limbs ( $F_{(3,33)} = 1.28$ ,  $p = 0.296$ ,  $\eta_p^2 = 0.014$ ). Similarly, the ankle dorsiflexion ROM showed no significant differences for the dominant ( $F_{(3,33)} = 1.30$ ,  $p = 0.289$ ,  $\eta_p^2 = 0.022$ ) or non-dominant limb ( $F_{(3,33)} = 2.51$ ,  $p = 0.075$ ,  $\eta_p^2 = 0.025$ ).

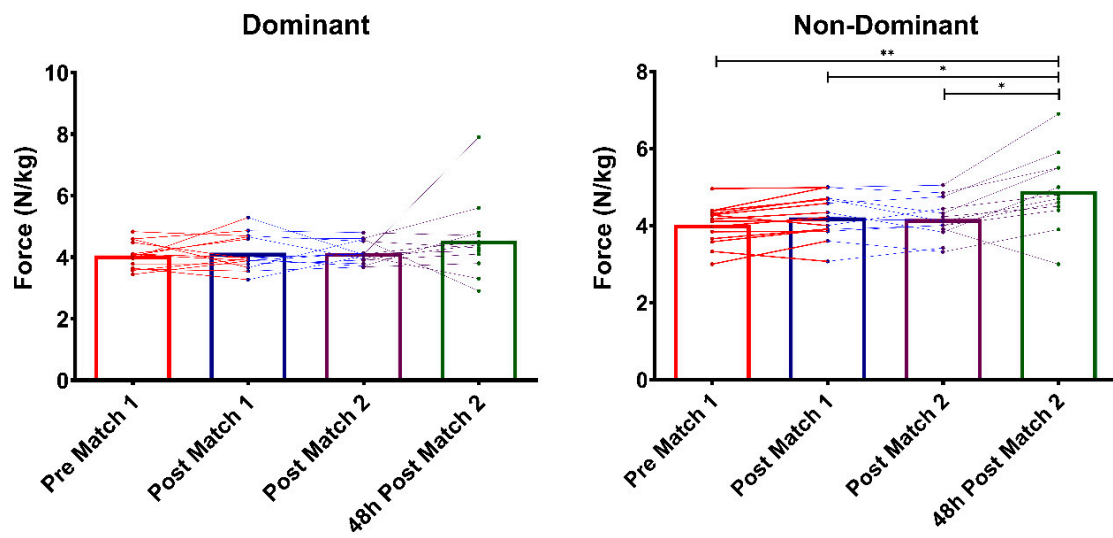
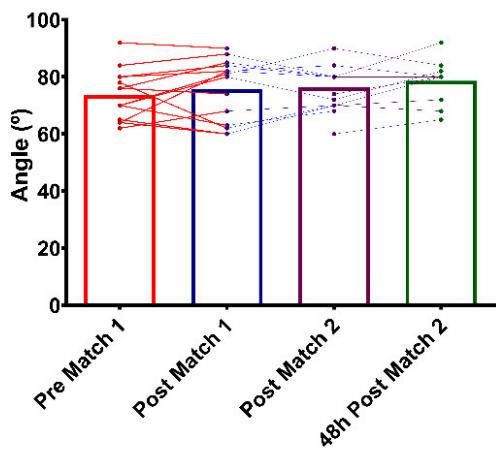
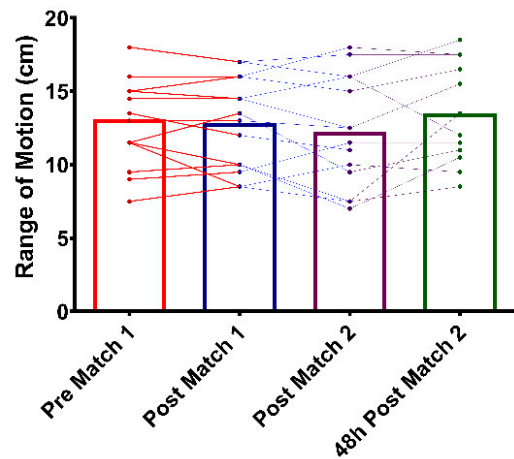


Figure 2. Mean and individual isometric knee flexion strength in the dominant and non-dominant limbs at the different tests. \* represents a significant difference at  $p < 0.05$ , and \*\* represents a significant difference at  $p < 0.001$ .

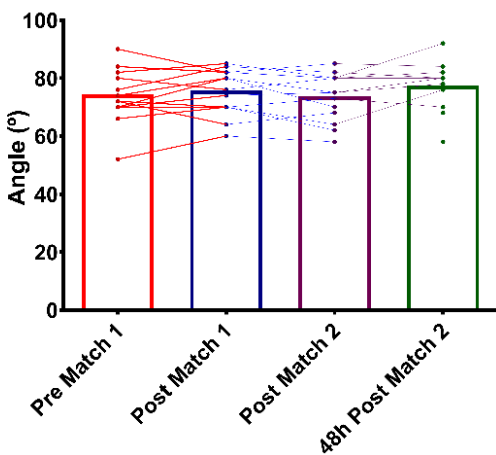
**Hip Flexion ROM in Straight Leg Raise Test  
Dominant**



**Ankle ROM Dominant**



**Hip Flexion ROM in Straight Leg Raise Test  
Non-Dominant**



**Ankle ROM Non-Dominant**

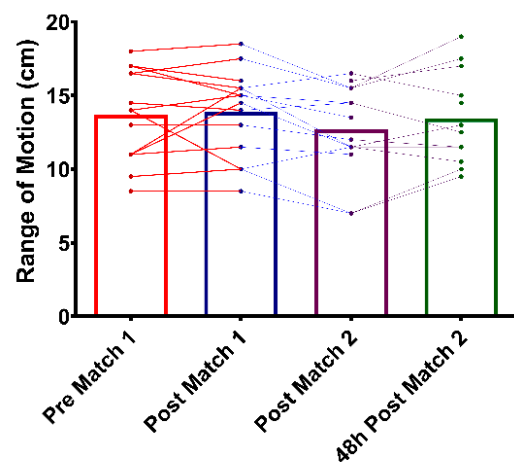
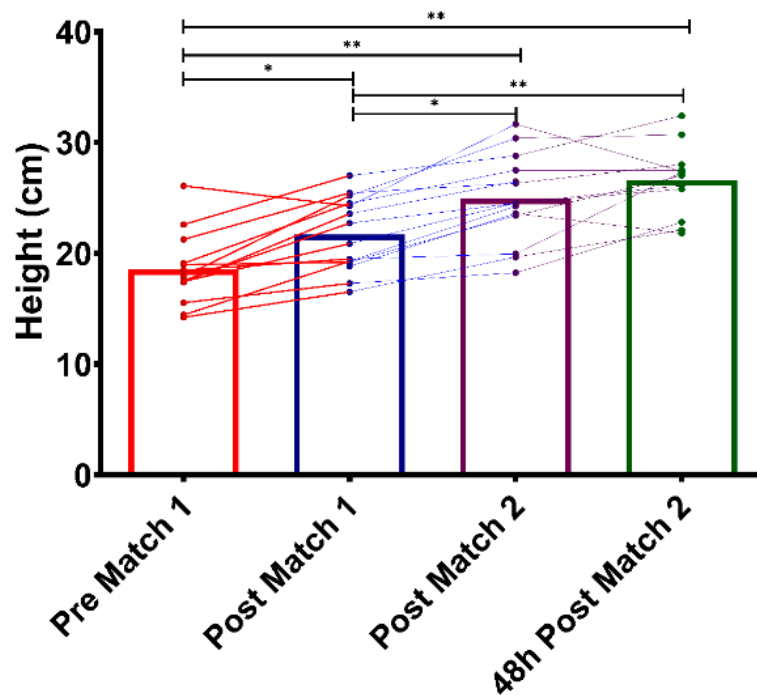


Figure 3. Mean and individual hip flexion and ankle dorsiflexion ROM in the dominant and non-dominant limbs.

Significant differences were obtained when comparing the CMJ height ( $F_{(3,33)} = 11.00$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.382$ ; Figure 4). The post hoc tests showed that pre-match 1 values were lower than at all other test moments ( $p \leq 0.003$ ). Moreover, post-match 1 values were lower than both tests before and after the second match ( $p \leq 0.004$ ).

### Vertical Jump with Counter Movement Jump



**Figure 4.** Mean and individual variations in the countermovement jump height at the different tests. \* represents a significant difference at  $p < 0.05$ , and \*\* represents a significant difference at  $p < 0.001$ .

#### 4. Discussion

This study examined the effect of two consecutive official league field hockey matches played within 24 h on lower-limb risk factors (strength, ROM, RPE) in female field hockey players. The main findings were that no differences between the identified risk factors, except for an increase in the isometric knee flexion strength in the non-dominant limb 48 h after the second competitive match and increased CMJ height over the matches.

No differences in isometric knee flexion strength were reported in the dominant leg; however, strength increases were reported in the non-dominant limb 48 h after the 2nd match (except for a single player, individual data values are plotted in Figure 2). This could be either due to a learning effect by the players or due to an absence of fatigue when performing these tests. In both cases, it could be argued that hamstring muscles do not accumulate excessive fatigue between matches, given that the distances covered at very high intensities and sprint speeds are low (Table 1) when compared to distances covered in other intermittent sports such as soccer [44], where soccer players cover greater distances at high intensities and sprint speeds when compared to field hockey players [4]. It has been shown in previous research that the hamstring muscles are most active at these high speeds [45], not having a predominant role at lower speeds [46]. In a previous study involving consecutive soccer matches, a decrease in hamstring strength was observed [32]. It is important to consider that the GPS-measured distances reported in this study are similar to values reported by Casamichana et al. [4] in 155 players, although they measured data over matches consisting of two halves of thirty-five minutes (as per the older rules), compared to four quarters of fifteen minutes in this study. The values were slightly lower than those reported by Morencos et al. [3] (9.99 m at  $>19$  km/h and 0.87 at  $>23$  km/h in match 1, 8.08 m at  $>19$  km/h, and 0.91 m at  $>23$  km/h in match 2), but this might be

explained due to Morencos et al. [3] studying hockey male players, while female players participated in this study [47]. There appears to be lower fatigue noted in the hamstring muscles as evidenced by the lack of significant differences between the values obtained in the straight leg raise test for either limb (Figure 3). A limited range of motion (ROM) has been considered a relevant risk factor for injuries in intermittent team sports in the lower limb [22]. However, an important characteristic of field hockey is the trunk flexion employed by the players when dribbling, passing, or shooting the ball with the stick, which could also influence the stretch and range of motion on the hamstrings. These results agree with a similar protocol carried out in tennis [48], which compared the hip range of motion before and after a single match. Similarly, no differences were obtained in the ankle range of motion for both the dominant leg and the non-dominant leg, a result that coincides with those of Wollin et al. [25] where the ankle dorsiflexion was not affected by this congested period of two matches [28]. These results suggest that the potential risk factors for hamstring injuries are not affected by playing two consecutive field hockey games. Although this might be in line with research recently published in soccer [49], one must remember that the majority of the distances run by the players has been at low and walking intensities, and the distances covered at medium or high instances are much smaller compared to soccer. Additionally, it is worth mentioning one of the characteristics of field hockey: a match is played over four quarters of fifteen minutes with rolling substitutions, allowing the players to recover when substituted. This is evident from the GPS registered data, which shows a difference in the total distance, but no differences when the playing time was considered. This can be further explained by the lack of neuromuscular fatigue seen in the lower-limb power as detected by the CMJ.

The CMJ showed a pattern of increasing successively over the games. The increase in values is contrary to previously published literature in different sports [5,50,51]. This finding could be explained by a couple of reasons. Firstly, a reduced, five-minute warm-up was performed in the pre-match 1 testing, focusing mainly on joint mobility exercises for the lower limb, since they went on to perform the match-specific warm-up after the tests, thus, warm-up intensity could have been insufficient. Secondly, the increase in the CMJ height could be linked to greater activation of the muscles of the tibialis anterior, gastrocnemius, and soleus muscles as a result of the large volume of medium-intensity runs performed during the match [52], which in turn, results in an optimal stiffness of the ankle and better transmission of the nerve impulses due to the increase in muscle temperature of active muscles [53]. These muscles play an important role in determining CMJ performance [54], and a greater activation could result in a better performance. However, it is important to note that the role of post-activation performance enhancement (PAPE) effects [55] elicited by actions during the game is unlikely for a couple of reasons: PAPE has a short-term, acute effect lasting for about five to thirty minutes [56], and the fact that no differences were seen between post-match 2 and 48 h post-match 2 values. Not only in the case of CMJ values, but looking at all data, it appears that the 48 h of recovery permitted a complete recovery following participation in consecutive matches. Moreover, in other studies featuring field hockey [57] or ice hockey players [58], PAPE has had minimal or no effect on performance.

### *Limitations*

The current investigation has several limitations. Firstly, the results of this study must be treated with caution given that not all players played the same number of minutes, resulting in the individual variation of the data, as previously reported. Nevertheless, this reflects a professional setting and shows the real demand the elite players are exposed to during a game. Perhaps definitive results can be obtained by following the team over an entire season, and not just a single period of two matches. Secondly, the tests were chosen so that they could be carried out before and after a match in the players' dressing room itself and used inexpensive material for rapid tests to identify risk factors of hamstring injuries. All tests were carried out in random order to ensure that all players were able to perform the tests without having to wait, and only peak values were used for analyses [26].



Finally, the sample only included female hockey players; it remains to be seen if the effects associated with repeated exposure matches in a short period (i.e., 24 h) are similar in men's field hockey players who tend to cover more distances at higher intensities.

## 5. Conclusions

Based upon the findings of this study, we conclude that two consecutive official league field hockey matches played within 24 h did not have a negative effect on lower-limb risk factors (strength, ROM, RPE) in female field hockey players directly and improved 48 h after the matches. However, surprisingly, it had a positive effect on explosive performance, as measured with the CMJ. This was probably due to a reduced warm-up before the first testing session and better nerve transmissions in activated muscles of the lower limb.

**Author Contributions:** Conceptualization, V.S.-M., A.L.-S., V.M.-P., and A.N.; methodology, V.S.-M., A.L.-S., V.F.-R., S.G., and J.B.D.-M.; software, A.N.; formal analysis, V.S.-M. and A.N.; investigation, V.S.-M., V.M.-P., and A.N.; resources, V.S.-M., V.F.-R., S.G., and J.B.D.-M.; data curation, A.N.; writing—original draft preparation, V.S.-M., V.M.-P., R.v.d.T., and A.N.; writing—review and editing V.S.-M., A.L.-S., V.M.-P., R.v.d.T., and A.N.; visualization, R.v.d.T. and A.N.; supervision, V.M.-P. and A.N.; project administration, V.M.-P.; funding acquisition, A.L.-S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study was partially funded by Universidad Francisco de Vitoria and Banco Santander via grants (UFV2021-44).

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Universidad Francisco Vitoria (45/2018).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data available on request.

**Acknowledgments:** The authors would like to thank the participants of the study for permitting the data collection during the tournament.

**Conflicts of Interest:** The authors declare no conflict of interest.

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