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The influence of substitution strategies on the physical match performance of elite female field hockey players

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ABSTRACT

The study aims were to i) compare movement demands of different substitution strategies for each position in elite female field hockey and ii) compare the effect substitutions had on match intensities post-substitution. During 19 international matches, movement data from 26 international players were collected. Substitution strategies were categorised into 5-min, 7.5-min, 10-min, at random intervals and full quarter play. Small reductions in work-rate were found from quarter 1 to 4 across positions despite running intensities not differing between quarters. Work-rate was greater for starting players during the opening minute and was also higher when compared to players coming off the bench. However, players coming off the bench had higher running intensities during this first minute with higher work-rates after minute two compared to the quarter average. Small differences in work-rate were found between substitution strategies for strikers and midfielders, with no differences in intensity for any position. In conclusion, a decrease in work-rate during the match suggests fatigue, but because intensity was maintained throughout, pacing strategies could be present. Although the substitution strategy utilised did not produce substantial results, the "first-minute-rush-effect" was confirmed as players coming off the bench were able to match and, in some cases, increase the work-rate.

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GPS; work-rate; rotation; hockey; movement; fatigue

1. Introduction

Field hockey is characterised as an intermittent team sport based on the physical and physiological demands placed on players during practice and competition (Kapteijns et al., 2021; Lemmink & Visscher, 2006; McMahon & Kennedy, 2019). But since 2015 international field hockey matches are played in four 15-minute quarters instead of two 35-minute halves resulting in matches being more intense with match loads for internal (heart rate) and external (relative distance)

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loads reported to be higher (Ihsan et al., 2021; McGuinness et al., 2019; Morencos et al., 2018). Since unlimited substitutions were introduced (FIH, 2014), coaches have the option to use substitutes as a tactic to mitigate the increased match intensity and sustain a fast-paced playing style. Unlimited substitutions entail that there is no limit to the number of players who can be substituted at the same time or to the number of times a single player can be substituted throughout the course of a match. Coaches can, for instance, substitute a whole striker line several times throughout a match. Pan et al. (2023) found that in football substitution players increased the match intensities compared to the players that were substituted. Therefore, the effective timing and frequency of substitutions could become an important tactic to optimise performance and reduce the effect of fatigue (Linke & Lames, 2016). Furthermore, a recent article (Spooner et al., 2023) indicated that future research should also investigate the optimal substitution strategies for each positional group due to differences in match demands between positions.

Few studies have investigated the practical use of substitutions and the effect it has on the field-hockey match demands. Linke and Lames (2016) found that international male strikers entering the field of play had a "first minute rush effect" covering 158 m/min during this first minute. However, within four minutes of being substituted they experienced a significant decrease in distance covered. On the other hand, Lythe and Kilding (2013) found that a greater substitution frequency did not increase the intensity of a match, but there was a tendency towards offsetting the decrements in match intensity due to fatigue. Although these studies gave researchers an initial insight into the effect substitution strategies could have on match demands, these studies were done only on strikers and the matches were played according to the previous format. Instead of using actual matches, Spooner et al. (2023) investigated various substitution strategies using match-simulated exercises based on the four-quarter match pattern. They concluded that during match-simulated exercise, both short (2 min) and long (5.5 min) rest times were enough to preserve physical performance. Also, a study done by McMahon and Kennedy (2019) showed that the general intensity of international female hockey matches increased during the current match format compared to the previous match format. Several studies also showed that despite having unlimited substitutions there was a decline in total distance covered and distance covered in high intensity running between the first and fourth quarters (McGuinness et al., 2019; Morencos et al., 2018). The question therefore begs whether with the increase in match intensities under the current match format, substitutions entering the field of play can increase the intensity or at least match the intensity of the substituted players?

The aims of this study are to i) compare the match demands of different substitution strategies for each positional group and ii) compare the effect substitutions had on match intensities in the post-substitution time periods. Due to differences in match demands between positional groups, it is hypothesised that there will be significant differences in match demands for different substitution strategies for strikers, midfielders and defenders. It is also hypothesised that players entering the field will significantly increase the intensity of the positional group.

2. Methods and materials

2.1. Participants

Twenty-six international female hockey players (age 22.1 ± 2.5 y; stature 172.5 ± 7.5 cm; mass 63.5 ± 9.6 kg) were assessed during the International Summer test series ($n = 9$ matches), World league ($n = 7$ matches) and World cup ($n = 3$ matches) tournaments. The Summer series and World league matches were played in South Africa whereas the World Cup matches were played in England. None of the matches were knock-out matches. During the research period, the players all belonged to the same team and was ranked in the top 15 globally. Players gave informed consent, and the study was approved by the Health Research Ethics Committee of the university (NWU-00965-19-A1). All matches were official and played on a standard artificial water-based turf in compliance with FIH regulations. The players were divided into three positional groups, namely strikers ($n = 9$ players; 99 files), midfielders ($n = 8$ players; 86 files) and defenders ($n = 9$ players; 101 files). Goalkeepers were not included in the study.

2.2. Methodology

Matches were monitored with global positioning system (GPS) units sampling at a frequency of 10 Hz (MinimaxX S4, Catapult Innovations, Victoria, Australia). The average number of satellite signals was 10.1 ± 0.1 and horizontal dilution of precision, 0.96 ± 0.05. Recordings from GPS units were downloaded to a PC, analysed with the Logan Plus V4.7.1 software (Catapult Sports, Victoria, Australia) and exported to a customisable Excel spreadsheet. GPS Doppler data was used during analyses of the GPS-related variables. The 10 Hz GPS unit is regarded as a valid and reliable device for measuring instantaneous velocity. Validity for constant velocity ($r = 0.96$; $r = 0.97$), acceleration ($r = 0.98$) and deceleration ($r = 0.98$; $r = 0.99$) have been established (Varley et al., 2012). They further established that the units were also found to be reliable for detecting instantaneous velocity (coefficient of variation 1.9–6.0%). Further, Johnston et al. (2014) showed that the inter-unit reliability of the 10 Hz devices was good when peak speed was measured (typical error of measurement 1.64%). Before commencement of each match, the GPS unit was fitted to the upper back of each player using a harness provided by the manufacturer before the warm-up started. This gave ample time for the GPS units to lock in satellites before match recordings started. The GPS unit provided data relating to the distance, PlayerLoad™ (PL) and velocity. The following movement categories were used for: high-intensity running (HIR) (4.5–5.6 m/s), and very high-intensity running (VHIR) (>5.7 m/s) (McGuinness et al., 2021; Vescovi & Frayne, 2015). Players had to maintain a specific velocity for at least 1 sec for a movement to be recorded as an effort. PL is an arbitrary unit defined as an "instantaneous rate of change of acceleration divided by a scaling factor". The relative distances covered during the match and in each velocity zone together with relative PL were used during analysis.

Substitutions were semi-controlled, allowing players to decide when the ideal time is to enter the playing field. Due to play not stopping for substitutions, players stand next to the side line for the scheduled substitution and then enter the field as soon as the substituted player can move off the field. In accordance with this, the planned substitution strategy was categorised into five groups; players subbed at 5-min

intervals (Sub5), at 7.5-min intervals (Sub7.5); at 10-min intervals (Sub10); at random intervals (R) and players who played the full quarter (FQ). Each match was divided into 1-min periods during which the relative (m/min) total distances covered in each velocity zone by players during that period, as well as the relative player load (PL/min) was measured. For the data of the 1-min period to be included in the analyses, the player had to spend at least 10-sec on the field and covered at least 20 m during that minute. In addition to the above-mentioned movement data additional coding for substituted players were recorded for the first, second, third, fourth and fifth minute after entering the playing field. A distinction was made between "starting" (Strikers = 172 files, Midfielders = 252 files, Defenders = 315 files) and "off the bench" (Strikers = 258 files, Midfielders = 150, Defenders = 66) players. Starting players refer to players who started each quarter after between-quarter breaks. Off the bench players refer to players who come off the bench and enter the field during play.

2.3. Statistical analyses

The Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) was used to process the data. The descriptive statistics of each variable for each positional group was drawn first and reported as mean ± SD. A linear mixed model analysis with an autoregressive 1 (AR1) structure was used to determine: 1) if there were statistically significant differences between match quarters, 2) differences between the movement data between the first five minutes of players who started the quarter compared to players entering the playing field during the quarter and 3) differences between substitution strategies throughout the match. Data was split for each position with players entered as subjects and Quarters (1), Substitution periods (2) and Substitution strategy (3) entered as fixed effects. Match was added as random effects. The p-value was set at $p < 0.05$. A Bonferonni post-hoc test was used to determine where the significant differences lie between variables. In addition, Cohen effect size and 95% CI was also used to determine the practical significance between the different measures. Magnitudes of standardised effects was assessed as 0–0.2 trivial, 0.3–0.6 small, 0.7–1.2 moderate, 1.3–2.0 large, and > 2.0 very large (Batterham & Hopkins, 2006). The effect was reported as unclear when the 95% CI of the standardised difference crossed the threshold for both substantially positive (0.2) and negative (−0.2) values.

3. Results

Table 1 contains movement data for all players irrespective of substitution strategy employed. When comparing the movement data for each positional group between quarters, there are several significant changes regarding the relative distance covered and relative player load. The relative distance for strikers ($p < 0.028$; ES:0.14–0.25), midfielders ($p < 0.002$; ES:0.17–0.32) and defenders ($p < 0.001$; ES:0.20–0.38) were significantly higher during the first quarter compared to quarter 2, 3 and 4. The same result was also seen when considering relative player load for strikers ($p < 0.005$; ES:0.17–0.28), midfielders ($p < 0.002$; ES:0.14–0.31) and defenders ($p < 0.001$; ES:0.26–0.47), with players gaining higher player load values during the first quarter compared to

Table 1. Descriptive statistics (mean ± SD) of movement data for all players during each quarter for each positional group.

Variables	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Sig. diff
Strikers					
Rel. distance covered (m/min)	123.1 ± 34.4	114.4 ± 34.2	118.1 ± 36.5	114.1 ± 37.1	Q1>Q2^{S},3^{T},4^{S}
Rel. player load (AU/min)	13.2 ± 4.1	12.5 ± 4.0	12.5 ± 4.2	12.0 ± 4.2	Q1>Q2^{T},3^{T},4^{S}
HIR (%)	6.6 ± 8.4	6.6 ± 9.3	6.7 ± 8.9	6.5 ± 8.8	
VHIR (%)	1.6 ± 4.9	1.9 ± 5.4	2.1 ± 5.9	1.9 ± 5.7	
Midfielders					
Rel. distance covered (m/min)	124.5 ± 30.9	118.3 ± 34.4	118.9 ± 34.0	113.9 ± 34.8	Q1>Q2^{T},3^{T},4^{S} Q4<Q2^{T},3^{T}
Rel. player load (AU/min)	12.1 ± 3.4	11.7 ± 3.7	11.3 ± 3.6	11.0 ± 3.7	Q1>Q2^{T},3^{T},4^{S} Q4<Q2^{T}
HIR (%)	7.4 ± 8.8	7.8 ± 9.5	7.4 ± 8.8	7.3 ± 9.2	
VHIR (%)	2.2 ± 5.8	2.4 ± 6.1	2.4 ± 5.1	2.6 ± 6.9	
Defenders					
Rel. distance covered (m/min)	113.9 ± 29.5	106.3 ± 31.6	107.8 ± 30.2	102.5 ± 30.6	Q1>Q2^{S},3^{T},4^{S} Q4<Q2^{T},3^{T}
Rel. player load (AU/min)	10.6 ± 3.0	9.8 ± 3.2	9.7 ± 3.1	9.1 ± 3.1	Q1>Q2^{S},3^{S},4^{S} Q4<Q2^{T},3^{T}
HIR (%)	4.9 ± 7.5	4.9 ± 7.7	4.7 ± 7.6	4.8 ± 7.8	
VHIR (%)	0.9 ± 3.5	1.2 ± 4.3	1.1 ± 4.4	1.3 ± 4.8	
Total group					
Rel. distance covered (m/min)	119.8 ± 31.7	112.2 ± 33.6	114.1 ± 33.7	109.3 ± 34.3	Q1>Q2^{T},3^{T},4^{S} Q4<Q2^{T},3^{T}
Rel. player load (AU/min)	11.8 ± 3.6	11.1 ± 3.8	11.0 ± 3.8	10.5 ± 3.8	Q1>Q2^{T},3^{T},4^{S} Q4<Q2^{T},3^{T}
HIR (%)	6.2 ± 8.2	6.2 ± 8.8	6.1 ± 8.5	6.0 ± 8.6	
VHIR (%)	1.5 ± 4.7	1.8 ± 5.2	1.8 ± 5.4	1.9 ± 5.8	Q1<Q4^{T}

Rel.-Relative, AU-Arbitrary unit, HIR-High intensity, VHIR-Very high intensity running, Qtr/Q-Quarter, Sig. diff-significant difference, T-Trivial effect size, S-Small effect size.

the second, third and fourth quarter. Relative distance for midfielders during the final quarter was significantly lower when compared to quarter 2 ($p = 0.028$; ES:0.13) and quarter 3 ($p = 0.006$; ES:0.15). Similarly, defenders covered less relative distance and had lower relative player load values during quarter 4 compared to quarter 2 ($p = 0.009$; ES:0.12 and $p < 0.001$; ES:0.20, respectively) and quarter 3 ($p < 0.001$; ES:0.17 and $p < 0.001$; ES:0.17, respectively). All differences between positions as well as for the total group varied between trivial and small. There were no significant differences between quarters for any of the positional groups with regards to HIR and VHIR.

Figure 1 represents the movement data during the first five minutes for strikers who started the quarter as well as the first five minutes of the strikers after entering the field of play. The strikers who started each quarter covered significantly greater relative distances ($p < 0.001$) during the first minute compared to strikers coming off the bench during the same period. For both relative PL ($p < 0.001$; ES = 1.04 [0.85–1.22]) and relative distance covered ($p < 0.001$; ES = 0.87 [0.69–1.04]) values during the first minute was significantly higher than the match average for players starting the quarter. However, for HIR the strikers that came off the bench achieved higher values during the first minute ($p = 0.007$) compared to the strikers who started the quarters. Also, for VHIR the strikers who came off the bench had higher values for the second minute ($p = 0.010$). On the other hand, the strikers who stater the quarter had significantly less VHIR for the first ($p = 0.002$; ES = 0.24 [0.09–0.39]) and second minute ($p < 0.001$; ES = 0.36 [0.20–0.52] of the quarter compared to the quarter average.

For the midfielders, the relative distance covered and PL during the first minute was significantly higher ($p < 0.001$; 3.5 and 4.4% higher than match average,

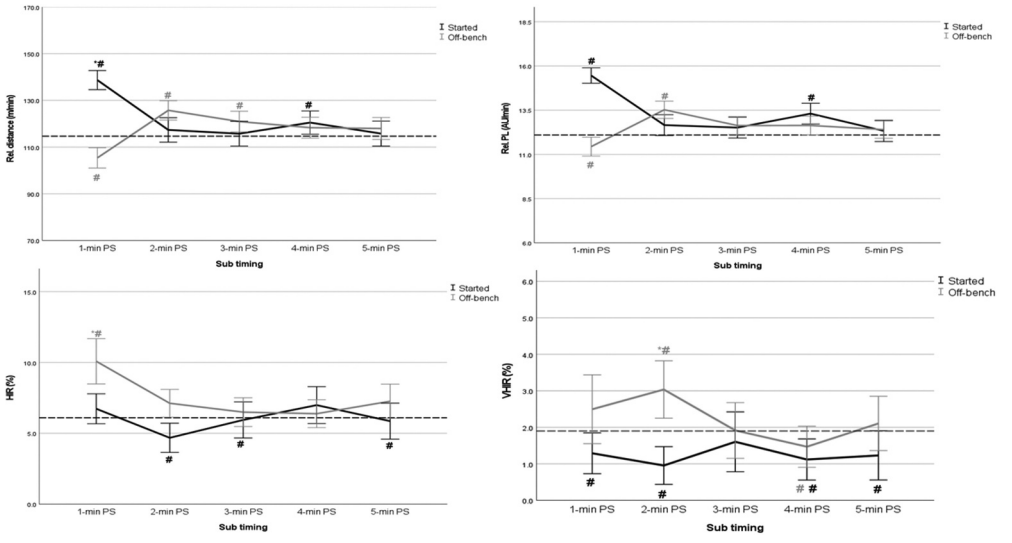

Figure 1. Movement data of the first 5 minutes of strikers who started the quarter and those that came off the bench. Rel – Relative; PS – post-sub. Dotted reference line: match average. * -significant difference between starting and off-bench players. # - significant difference between time point and quarter average.

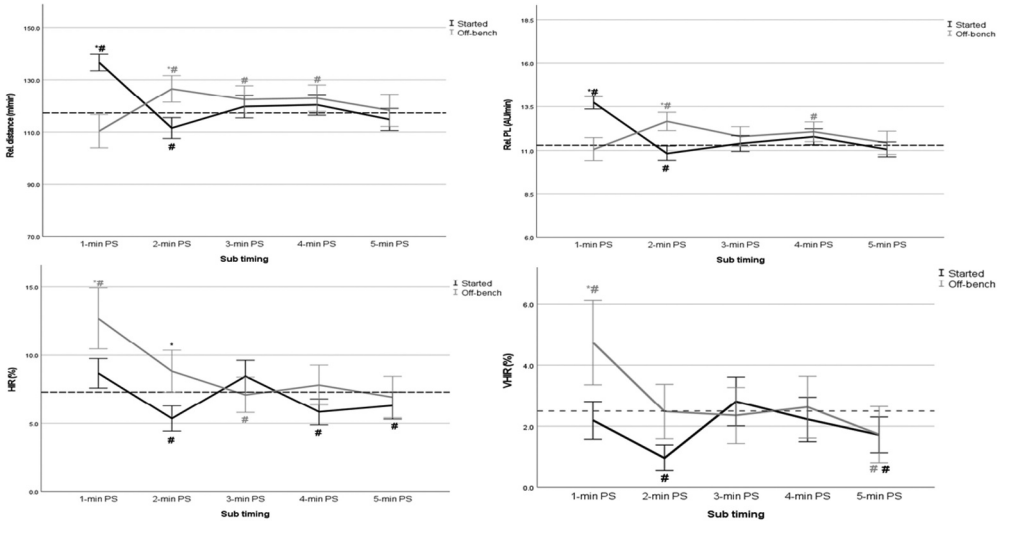

Figure 2. Movement data of the first 5 minutes of midfielders who started the quarter and those that came off the bench. Rel – Relative; PS – Post-sub. Dotted reference line: match average. * -significant difference between starting and off-bench players. # - significant difference between time point and quarter average.

respectively) for the players starting compared to the midfielders who came off the bench, however during minute two the players who came off the bench covered significantly more ($p < 0.001$; 1.6% and 2.4% higher than match average) relative distance compared to the starters (Figure 2). However, midfielders who came off

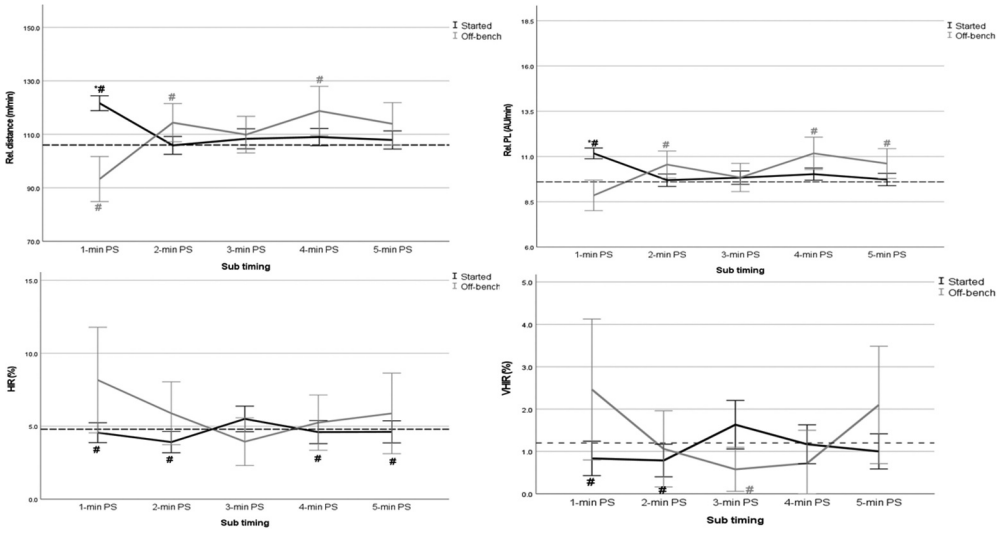

Figure 3. Movement data of the first 5 minutes of defenders who started the quarter and those that came off the bench. Rel – Relative; PS – Post-sub. Dotted reference line: match average. * -significant difference between starting and off-bench players. # - significant difference between time point and quarter average.

the bench could then cover significantly more relative distance during minute two ($p < 0.001$; ES = 0.31 [0.15–0.47]), three ($p = 0.035$; ES = 0.17 [0.01–0.34]) and four ($p = 0.017$; ES = 0.20 [0.04–0.37]) compared to the quarter average. Likewise, the midfielders who came off the bench covered significantly more HIR during the first ($p = 0.001$; 13% higher than match average) and second minute ($p = 0.012$; 4.3% higher than match average) compared to the starters, with VHIR also being higher ($p = 0.005$; 16.3% higher than match average) for the benched players compared to the starting midfielders during the first minute.

The defenders who started each quarter covered significantly greater relative distances ($p < 0.001$; 3.1% higher than match average) and PL ($p < 0.001$; 3.4% higher than match average) during the first minute compared to defenders coming off the bench during the same period (Figure 3). But, during the first minute defenders coming off the bench covered significantly more HIR ($p = 0.032$; 12.8% higher than match average) compared to starters. There were however no significant differences between starters and benched defenders for VHIR. Comparing relative distance and PL of defenders starting the quarter to the quarter average after the first minute, no significant differences were found with some significant ($p < 0.05$) differences for HIR and VHIR, but none of them were practically significant (ES > 0.2).

With regards to difference in timing strategies, presented in Table 2, the only significant differences were for relative distance covered and relative PL by strikers, midfielders and the total group. All these differences however ranged from trivial to small. They had lower relative PL when compared to 7.5S and 10S with a small effect size. There were no significant differences for HIR or VHIR in any of the positional groups.

Table 2. Movement data (mean ± SD) of all players for each substitution strategy according to position.

Variables	5S	7.5S	10S	R	FQ	Sig. diff
Strikers						
Rel. distance covered (m/min)	116.3 ± 36.1	119.0 ± 34.9	118.4 ± 34.8	112.8 ± 39.5	112.4 ± 36.7	$R < 7.5S^{T}$
Rel. player load (AU/min)	12.5 ± 4.1	12.6 ± 4.0	12.7 ± 4.3	12.1 ± 4.5	11.5 ± 4.3	$FQ < 7.5S^{S}$, $10S^{S}$
HIR (%)	7.0 ± 9.4	6.3 ± 8.7	6.6 ± 8.4	6.5 ± 9.4	6.2 ± 8.0	
VHIR (%)	1.8 ± 5.4	1.7 ± 5.1	2.1 ± 6.2	2.1 ± 5.7	1.9 ± 5.3	
Midfielders						
Rel. distance covered (m/min)	121.0 ± 35.3	119.9 ± 31.1	121.2 ± 33.4	120.1 ± 33.7	115.5 ± 34.0	$FQ < 5S^{T}$, $10S^{T}$, R^{T}
Rel. player load (AU/min)	11.9 ± 3.9	11.8 ± 3.5	11.8 ± 3.6	11.4 ± 3.5	11.3 ± 3.7	$5S > R^{T}$, FQ^{T} $FQ < 10S^{T}$
HIR (%)	8.1 ± 9.2	7.3 ± 8.9	7.9 ± 9.3	7.6 ± 9.3	6.9 ± 8.8	
VHIR (%)	2.8 ± 6.8	2.3 ± 5.9	2.5 ± 6.3	2.5 ± 6.4	2.2 ± 6.3	
Defenders						
Rel. distance covered (m/min)	108.4 ± 31.9	110.6 ± 31.2	109.0 ± 32.3	108.0 ± 31.3	107.1 ± 30.5	
Rel. player load (AU/min)	10.2 ± 3.3	10.0 ± 3.1	9.7 ± 3.1	9.5 ± 3.1	9.8 ± 3.1	
HIR (%)	5.4 ± 9.1	4.6 ± 7.9	5.4 ± 7.9	5.1 ± 7.9	4.8 ± 7.5	
VHIR (%)	1.2 ± 4.2	1.9 ± 5.8	1.6 ± 5.9	1.2 ± 4.2	1.1 ± 4.1	
Total group						
Rel. distance covered (m/min)	116.9 ± 35.6	118.5 ± 33.8	117.7 ± 34.1	115.7 ± 34.8	109.3 ± 31.8	$FQ < 5S^{T}$,$7.5S^{T}$,$10S^{S}$,R^{T}
Rel. player load (AU/min)	12.1 ± 4.0	12.2 ± 3.9	11.9 ± 4.0	11.1 ± 3.8	10.2 ± 3.4	$FQ < 5S^{S}$,$7.5S^{S}$,$10S^{S}$,R^{S} $R < 5S^{S}$,$7.5S^{S}$,$10S^{T}$
HIR (%)	7.2 ± 9.3	6.4 ± 8.7	6.8 ± 8.7	6.8 ± 9.1	5.3 ± 7.9	$FQ < 5S^{T}$,$7.5S^{T}$,$10S^{T}$,R^{T}
VHIR (%)	2.1 ± 5.8	1.8 ± 5.4	2.2 ± 6.2	2.1 ± 5.8	1.4 ± 4.7	$FQ < 5S^{T}$,$7.5S^{T}$,$10S^{T}$,R^{T}

Rel.-Relative, AU-Arbitrary unit, HIR-High intensity, VHIR-Very high intensity running, Qtr/Q-Quarter, Sig. diff-significant difference, 5S–5-min substitution, 7.5S–7.5-min substitution, 10S–10-min substitution, R-random substitution, FQ-Full quarter, T-Trivial effect size, S-Small effect

4. Discussion

The question addressed in this study was whether substitutions entering the field of play can increase the intensity or at least match the intensity of the substituted players? We therefore compared the match demands of different substitution strategies for each positional group and compared the effect substitutions had on match intensities in the post-substitution time periods. The main findings of this study were 1) that there was a significant decline in work-rate between quarters, despite the availability of unlimited substitutions 2) especially in the first minute there were significant differences between the amount and intensity of work done between starters and players entering the field, and 3) the substitution strategy used had a very small influence on the work-rate of players.

The first main finding was that even though unlimited substitutions were available there was still a small but significant decrease in the amount of work (relative distance and Playerload) done from Q1 to Q4 for all positional groups even though the intensities (HIR and VHIR) did not differ significantly between quarters (Table 1). The results from this study are similar to the study by Kapteijns et al. (2021) who also found a significant decline in work-rate (m/min) from Q1 to Q4, however in contrast to this study they also found a decrease in HIR. Our results seem to suggest that although the amount of work declined as the match progressed, players were still able to keep the intensity constant throughout the match, suggesting that pacing might be involved. Recent results from McGuinness et al. (2021) supports this notion of pacing in field hockey with further evidence provided in sports like football (Bradley & Noakes, 2013; Sparks et al., 2016).

The second major finding is that work-rate (relative distance and PL) was significantly greater than the quarter average for starting players (in all positions) during the opening minute, and it was also significantly higher when compared to players coming off the bench (Figures 1–3). However, it seems that the intensity of work done (HIR and VHIR) by the starting line-up during the first two minutes was significantly lower than the quarter average across all positions. Whereas players coming off the bench had higher, although not always significant, running intensities (HIR and VHIR) compared to the quarter average. This finding is similar to the study by Linke and Lames (2016) who also found that players re-entering the field had a "first-minute-rush-effect", however in their study this rush-effect was based on relative distance covered and not HIR or VHIR. Nevertheless, this rush-effect could occur because players race to take their positions as soon as possible because time does not stop when they are substituted. Interestingly though after the first minute of play there were no significant differences (with the exemption of VHIR for strikers during minute two) in the work-rate or intensity of work between players who started the quarter and those who came off the bench. Yet after the first minute, strikers, midfielders and defenders who came off the bench showed small to moderate significant increases in relative distance covered and PL after the first minute compared to the quarter average. These results support the notion presented by Bradley et al. (2014) that substitutions in football should be able to match or even surpass the work-rate of players remaining on the pitch. In contrast to Linke and Lames (2016) however, the results in this study do not support a significant decline in intensity

towards minute four and five. Although not significant, defenders and strikers in this study tended to have a higher than quarter average intensity towards the 4th and 5th minute. It should however be noted that the study by Linke and Lames (2016) analysed only male strikers during three matches, which might account for the differences in results.

Finally, there were few differences in work-rate varying from trivial to small when comparing substitution strategies for strikers and midfielders, with no significant differences between any of the intensity variables for any position (Table 2). Although not significant, FQ players did present with less activity across all variables. These findings are in agreement with Lythe and Kilding (2013) who found that although no-substitution -conditions did result in lower total distance covered, increasing the number of substitutions did not have any clear effect on heart rate responses, total distance covered, or distance covered at different intensities. When evaluating substitution strategies, caution should be exercised when basing conclusions only on movement data. Technical considerations such as the number of successful pass completions or attacking 25 entries should be taken into account when considering how often substitutions should be made. Although Lythe and Kilding (2013) had a very small sample size, their results suggest that a higher substitution frequency coincided with more attacking entries. Therefore, future studies should combine both movement data with technical data to gain a better understanding of which substitution strategies are most influential. Despite the fact that the current study comprised a reasonably large number of matches, it should be highlighted that the study's findings are restricted to the strategies of one team, despite the fact that it was against several different opponents, both higher and lower ranked than the team analysed.

5. Conclusion

In conclusion, the results from this study indicate that despite the availability of unlimited substitutions, there were small but significant decreases in work-rate from Q1 to Q4, however players were able to maintain their intensity as the match progressed. This might indicate some form of pacing strategy used by players. Although the type of substitution strategy used did not yield any significant findings with regards to work-rate and intensity, there were significant results when comparing the movement data of substituted players during the first five minutes on the field. The findings corroborate the notion of a "first-minute-rush-effect" experienced by players coming off the bench, however this high intensity faded after the first minute. Players coming off the bench, on the other hand, were able to match and, in some cases, increase the work-rate compared to the quarter average. Collectively, these findings provide insight into the impact substitutes have on match work-rate and intensity, but future studies should include technical data to get a full picture of their impact.

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Disclosure statement

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References

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57. https://doi.org/10.1123/ijspp.1.1.50

Bradley, P. S., Lago-Peñas, C., & Rey, E. (2014). Evaluation of the match performances of substitution players in elite soccer. *International Journal of Sports Physiology and Performance*, *9*(3), 415–424. https://doi.org/10.1123/ijspp.2013-0304

Bradley, P. S., & Noakes, T. D. (2013). Match running performance fluctuations in elite soccer: Indicative of fatigue, pacing or situational influences? *Journal of Sports Sciences*, *31*(15), 1627–163. https://doi.org/10.1080/02640414.2013.796062

FIH. (2014). *FIH media release*. Retrieved April 22, 2020, from http://www.fih.ch/files/pictures/news/2014%20News%20Photos/FIH%20%20Media%20Release%20-%2020th%20March%202014%20-%20FIH%20changes%20match%20format%20from%20two%20halves%20to%20four-quarters.pdf

Ihsan, M., Yeo, V., Tan, F., Joseph, R., Lee, M., & Aziz, A. R. (2021). Running demands and activity profile of the new four-quarter match format in men's field hockey. *Journal of Strength and Conditioning Research*, *35*(2), 512–518. https://doi.org/10.1519/JSC.0000000000002699

Johnston, R. J., Watsford, M. L., Kelly, S. J., Pine, M. J., & Spurrs, R. W. (2014). Validity and interunit reliability of 10 hz and 15 hz GPS units for assessing athlete movement demands. *Journal of Strength and Conditioning Research*, *28*(6), n1649–1655. https://doi.org/10.1519/JSC.0000000000000323

Kapteijns, J., Caen, K., Lievens, M., Bourgois, J. G., & Boone, J. (2021). Positional match running performance and performance profiles of elite female field hockey. *International Journal of Sports Physiology and Performance*, *16*(9), 1295–1302. https://doi.org/10.1123/ijspp.2020-0337

Lemmink, K. A. M. P., & Visscher, S. H. (2006). Role of energy systems in two intermittent field tests in women field hockey players. *Journal of Strength and Conditioning Research*, *20*(3), 682–688. https://doi.org/10.1519/00124278-200608000-00033

Linke, D., & Lames, M. (2016). Substitutions in elite male field hockey–a case study. *International Journal of Performance Analysis in Sport*, *16*(3), 924–934. https://doi.org/10.1080/24748668.2016.11868939

Lythe, J., & Kilding, A. E. (2013). The effect of substitution frequency on the physical and technical outputs of strikers during field hockey match play. *International Journal of Performance Analysis in Sport*, *13*(3), 848–859. https://doi.org/10.1080/24748668.2013.11868693

McGuinness, A., Kenna, D., Grainger, A., & Collins, K. (2021). Investigating the effect of individual rotations on the physical and physiological performance in elite female field hockey players. *Applied Sciences*, *11*(3), 1022. https://doi.org/10.3390/app11031022

McGuinness, A., Malone, S., Petrakos, G., & Collins, K. (2019). Physical and physiological demands of elite international female field hockey players during competitive match play. *The Journal of Strength & Conditioning Research*, *33*(11), 3105–3113. https://doi.org/10.1519/JSC.0000000000002158

McMahon, G. E., & Kennedy, R. A. (2019). Changes in player activity profiles after the 2015 FIH rule changes in elite women's hockey. *The Journal of Strength & Conditioning Research*, *33*(11), 3114–3122. https://doi.org/10.1519/JSC.0000000000002405

Morencos, E., Romero-Moraleda, B., Castagna, C., & Casamichana, D. (2018). Positional comparisons in the impact of fatigue on movement patterns in hockey. *International Journal of Sports Physiology and Performance*, *13*(9), 1149–1157. https://doi.org/10.1123/ijspp.2017-0506

Pan, P., Li, F., Han, B., Yuan, B., & Liu, T. (2023). Exploring the impact of professional soccer substitute players on physical and technical performance. *BMC Sports Science, Medicine and Rehabilitation*, *15*(1), 143–154. https://doi.org/10.1186/s13102-023-00752-x

Sparks, M., Coetzee, B., & Gabbett, T. J. (2016). Variations in high-intensity running and fatigue during semi-professional soccer matches. *International Journal of Performance Analysis in Sport*, *16*(1), 122–132. https://doi.org/10.1080/24748668.2016.11868875

Spooner, T. W., West, A. T., & Willems, M. E. (2023). Effect of substitution time on physical, technical and cognitive performance in sub-elite male field hockey players. *International Journal of Exercise Science*, *16*(6), 497–512.

Varley, M. C., Fairweather, I. H., & Aughey1, 2, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, *30*(2), 121–127. https://doi.org/10.1080/02640414.2011.627941

Vescovi, J. D., & Frayne, D. H. (2015). Motion characteristics of division I college field hockey: Female athletes in motion (FAiM) study. *International Journal of Sports Physiology and Performance*, *10*(4), 476–481. https://doi.org/10.1123/ijspp.2014-0324