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Running title: Repeated high-intensity exercise in soccer

Repeated High-Intensity Running and Sprinting in Elite Women's Soccer Competition

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Abstract

Background: To our knowledge, no study has investigated the concurrent repeated, high-intensity (RHIA) and repeated-sprint activity (RSA) of intermittent team sport competition.

Purpose: In this study, we report on the RSA of elite Women's football competition. In addition, we describe the nature of RHIA (e.g. striding and sprinting activities) that involve a high energy cost and are associated with short duration (i.e. ≤20 seconds) recovery periods.

Methods: Thirteen elite women soccer players underwent video-based time-motion analysis on 34 occasions during national and international standard matches. RSA and RHIA were defined as successive (i.e. 2) sprints, or striding and sprinting efforts that occurred with ≤20 seconds between efforts.

Results: The number of RSA and RHIA bouts performed was similar between the first and second half of matches. Sprinting and striding/sprinting durations tended to remain relatively stable irrespective of the number of efforts in a RSA or RHIA bout, or the period of play. However, recovery duration between efforts increased in the second half, and when a greater number of efforts were performed per bout.

Conclusion: These findings suggest that first to second half reductions in RHIA and RSA do not occur in elite Women's soccer competition. However, players increase the amount of low-intensity recovery undertaken between RHIA and RSA efforts, most likely in an attempt to maintain RHIA and RSA performance. These findings emphasize the importance of repeated-sprint and effort ability to elite Women's soccer, and highlight the importance of training this quality to prevent reductions in performance during competitive match-play.

Keywords: time-motion analysis, high-speed running, repeated-sprint ability, training, team sports

Introduction

Repeated-sprint and prolonged high-intensity running ability are widely accepted as critical components of high-intensity intermittent team sports (e.g. soccer). In soccer competition it has been shown that periods of fatigue follow the most intense bouts of high-intensity running. [1] Reports on the relative importance of high-intensity running to elite male and female soccer performance are equivocal, with some, [2,3] but not all [4,5] studies demonstrating that elite players perform more high-intensity running than sub-elite competitors, and when the demands of competition are greatest. The number and intensity of repeated-sprint bouts has also been reported to be a significant discriminator of elite and sub-elite female soccer competition. [6] In a study of female soccer players, Gabbett and Mulvey [6] demonstrated that players performed on average, more repeated-sprint bouts in international matches (4.8 bouts per match) than national (1.0 bout per match) and domestic (1.4 bouts per match) matches. Importantly, the average number of sprints was greater, and recovery between sprints shorter in international competition. Collectively, these results suggest that repeated-sprint activity and the amount of high-intensity running performed may differ according to the competitive standard.

Despite the importance of high-intensity running [1,2] and repeated-sprint ability [6-8] to competitive success in high-intensity intermittent team sports, studies investigating the nature of repeated high-intensity activity in these sports are limited. [9-12] Spencer et al. [7] subjectively assessed the sprint and repeated-sprint demands of elite field hockey using video time-motion analysis. The authors reported that repeated-sprint bouts (defined as a minimum of 3 sprints, with ≤20 seconds recovery between sprints) occurred on 17 occasions throughout the match. The average number of sprints within the repeated-sprint bouts was 4 (± 1), with a mean recovery time of 14.9 seconds between sprint efforts. It has been suggested that while repeated-sprints occur infrequently, the ability or inability to perform these activities may prove critical to the outcome of the match, [7] although to date, limited evidence exists to support this claim. [8]

Although repeated-sprint activity provides an indication of the most demanding passages experienced during match-play, operational definitions of repeated-sprint ability (i.e. 3 or more sprints with ≤20 seconds recovery between sprints) may only provide a limited picture of the physically demanding running activities that occur in high-intensity, intermittent team sports. For example, repeated-sprint bouts may include a range of sprint effort frequencies, with relatively long or short recovery between efforts; reporting of the average demands alone may underestimate the most extreme demands that might be expected during competition. In addition, limiting repeated-sprint bouts to 3 or more sprints, effectively eliminates successive, short-recovery sprints that may also be physically demanding but fail to meet the traditional repeated-sprint criteria. [7] Equally, high-speed running (i.e. striding) efforts, which may also be separated by short recovery periods, are likely to make a substantial contribution to the energetic cost of competition, despite failing to qualify as repeated-sprint activity. An understanding of these repeated, high-intensity activity bouts would provide strength and conditioning coaches with evidence to inform conditioning programs in order to adequately prepare players for the repeated high-intensity (both striding and sprinting) demands of competition.

To our knowledge, no study has investigated the concurrent repeated, high-intensity activity (i.e. striding and sprinting) and repeated-sprint demands of intermittent team sport competition. In this study, we report on the repeated-sprint demands of elite Women's soccer competition, with special reference to the number of sprints within a bout, and the typical

sprint and recovery durations performed within these high-intensity activities. In addition, we describe the nature of repeated, high-intensity activities (e.g. striding and sprinting) that involve a high energy cost and are associated with short duration (i.e. ≤20 seconds) recovery periods, in order to document repeated high and very-high intensity exercise bouts in this sport.

Methods

Subjects

Thirteen elite women soccer players (mean ± SD age, 21 ± 2 years) participated in this study. Athletes were scholarship holders with the Queensland Academy of Sport women's soccer program and/or members of the Australian Matildas women's soccer team. All participants received a clear explanation of the study, including the risks and benefits of participation, and written consent was obtained. The institutional review board for human investigation approved all experimental procedures.

Time-Motion Analysis

Video-based time-motion analysis was performed during 10 national and 5 international standard competitive matches. Players were filmed and analyzed on 34 occasions (19 national and 15 international player appearances) over the course of the 15 matches. The mean ± SD number of national and international matches analyzed per player was 2.7 ± 1.1 and 2.1 ± 1.5, respectively. All matches were 90 minutes in duration, and played on a full-sized pitch (100 m length x 65 m width). Only outfield players (i.e., strikers, mid-fielders, and defenders) were filmed. No substitutes were filmed or analyzed in this study. All comparisons between the first and second half were made on the same player. Video recordings were made using digital video cameras (Sony, DCR-TRV 950E). Cameras were positioned in the stadium, on the half-way line, approximately 30 m above the field of play to cover the entire playing arena. The zoom function of the video camera was utilized during recording so that the image of the player and a 10 m radius of her surrounds was maintained. Up to four cameras were used in any given match, and players had no knowledge of who was being filmed for each match.

The video recordings were analyzed by one experienced observer by logging frequency and duration of the activities performed using purpose built software (Gab-Trakka, Brisbane, Australia). A description of all match-play activities is provided in Table 1. The initiation and completion of each individual activity were recorded, and the duration of each activity was calculated. The time spent standing, walking, and jogging was considered to be low-intensity exercise, with striding and sprinting regarded as high-intensity exercise. The typical error of measurement (% coefficient of variation, CV) for test-retest reliability for the activities of standing, walking, jogging, striding, and sprinting were 0.6%, 0.3%, 2.4%, 4.6%, and 3.5%, respectively.

Insert Table 1 About Here

Repeated-Sprint and Repeated High-Intensity Activity

Repeated-sprint activity (RSA) was defined in two ways. First, RSA was defined as a minimum of three sprints, with ≤20 seconds between sprints. [7] The mean, maximal, and minimal duration of sprints, number of sprint repetitions, and recovery duration were also recorded. To account for physically demanding repeated sprints that did not meet the traditional repeated-sprint definition, we also recorded successive (i.e. 2) sprints that occurred with ≤20 seconds between sprints. We also adapted this definition to record the frequency of

repeated high-intensity activity (i.e. a combination of striding and/or sprinting; RHIA) bouts. RHIA was defined as a minimum of two consecutive sprints or striding efforts, with ≤20 seconds between efforts.

Statistical Analysis

Differences in RSA and RHIA (striding and/or sprinting) demands between the first and second half of matches were analyzed using a practical approach based on the real world relevance of the results. [13] Differences in the RSA and RHIA demands between the first and second half of matches, and national and international competition were analyzed using Cohen's effect size (ES) statistic and 90% confidence limits (CL). Effect sizes of <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively. [13] Given our small sample size and that a wide between-match variability has been shown for the amount of high-speed running and sprinting performed in soccer,[14] a moderate effect size was chosen as our lower limit for observed differences. All data are reported as mean ± SD.

Results

The number of repeated-sprint and striding actions per bout when analyzed as sets of 2, 3, 4, 5, or 6 efforts are shown in Table 2. In general, there was wide variability in the number of RSA bouts performed among the different players, with 5.1 ± 5.1 (range = 0-23) RSA bouts performed per player per match. Sprint bouts consisting of successive sprints (i.e. 2 sprint efforts) were the most common type of RSA bout. Some players (N = 6, 17.7%) performed no repeated-sprint bouts, and others performed up to 23 repeated-sprint bouts in a match. The greatest number of sprints in any single bout was 7. The average sprint duration throughout the various RSA bouts was 2.17 ± 0.13 s, with sprint duration remaining relatively stable across short (i.e. 2 sprints; 2.27 ± 0.56 s) and long (i.e. 6 sprints; 2.08 ± 0.19 s) RSA bouts. However, the mean recovery duration progressively increased with a greater number of sprints per bout.

RHIA bouts that included a combination of striding and/or sprinting were more common than RSA bouts; players performed on average 31.2 ± 18.7 RHIA bouts per game. The most common type of RHIA bout involved 2 efforts. Repeated striding and sprinting activities that involved 6 efforts occurred on 11.1 ± 13.8 occasions per player, per game. The average stride and sprint duration throughout the various RHIA exercise bouts was 2.94 ± 0.05 s, with sprinting and striding durations remaining relatively stable across short (i.e. 2 sprint/stride efforts; 2.98 ± 0.66 s) and long (i.e. 6 sprint/stride efforts; 2.93 ± 0.67 s) RHIA exercise bouts. Consistent with RSA bouts, the mean recovery duration between sprinting and striding efforts progressively increased with a greater number of efforts per bout.

When analyzed as sets of 6 efforts, the average sprint duration in RSA bouts of international matches was greater (26.0 ± 24.2%, ES = 2.48) than national matches. No other meaningful differences (ES = 0.03-0.50) were found between national and international matches for average sprint duration in RSA bouts. No meaningful differences (ES = 0.08-0.29) were detected between national and international matches for the average effort duration of RHIA bouts.

The recovery duration of sets of 4 RSA bouts was moderately shorter (22.0 ± 20.3%, ES = 0.64) in international than national matches. However, only trivial to small differences (ES = 0.02-0.40) were observed between national and international matches for recovery durations between sprinting/striding efforts in RHIA exercise bouts.

Insert Table 2 About Here

While the small sample size limited our analysis of positional differences, the number of RSA bouts performed was generally higher in central mid-fielders (7.4 ± 4.5 national, *N* = 5; 10.0 ± 11.3 international, *N* = 3) than wide mid-fielders (1.0 ± 1.0 national, *N* = 3; 6 international, *N* = 1), strikers (6.0 ± 6.7 national, *N* = 5; 3.6 ± 2.3 international, *N* = 5), and defenders (5.3 ± 4.4 national, *N* = 6; 3.2 ± 2.3 international, *N* = 6). The number of RHIA bouts performed was also generally higher in central mid-fielders (37.8 ± 19.7 national, *N* = 5; 39.7 ± 35.2 international, *N* = 3) than wide mid-fielders (24.7 ± 9.1 national, *N* = 3; 6 international, *N* = 1), strikers (42.2 ± 20.6 national, *N* = 5; 26.8 ± 9.2 international, *N* = 5), and defenders (32.1 ± 21.1 national, *N* = 6; 20.7 ± 13.6 international, *N* = 6).

Possibly small differences (30%, CL ± 31%, ES = 0.29) were found between the first and second half of matches for the number of RSA (3.0 ± 3.2 *vs.* 2.1 ± 2.8) bouts performed. In addition, there was a possibly small decrease (14% ± 11%, ES = 0.22) in the number of RHIA bouts from the first (16.8 ± 11.3) to the second half (14.4 ± 10.0) of matches. In general, there was a greater frequency of RSA and RHIA bouts in the first 15 minutes of the match, with the frequency of RSA and RHIA bouts declining over the course of the match for both national and international players (Figure 1). After the half-time break there was a trend towards an increased number of RSA and RHIA bouts during the 45-60 min period, when compared to the two previous and subsequent periods.

Insert Figure 1 About Here

Figure 2 shows the first and second half recovery durations per RSA and RHIA bout, when analyzed as sets of 2, 3, 4, 5 or 6 efforts. RSA bouts were associated with very likely greater recovery durations between efforts for sets of 4 (22.3 ± 18.5%, ES = 0.67) and 5 (26.2 ± 5.7%, ES = 0.93) sprints, in the second half compared to the first half of matches. Approximately 88-90% of motion involved low-intensity activity. The time spent standing (5.4% *vs.* 8.5%), walking (36.5% *vs.* 30.4%), jogging (47.6% *vs.* 49.8%), and striding (10.4% *vs.* 11.3%) between RSA bouts changed differentially from the first to second half. Only trivial to small differences (ES = 0.01-0.33) were observed between the first and second half of matches for recovery durations between sprinting/striding efforts in RHIA exercise bouts. The percentage of time spent standing, walking, and jogging between RHIA bouts in the first and second half was 7.0% and 7.2%, 39.4% and 44.6%, and 53.6% and 48.2%, respectively.

Insert Figure 2 About Here

Figure 3 shows the percentage change in recovery duration between RSA bouts and RHIA bouts, expressed relative to sets of 2 RSA or RHIA exercise bouts. Moderate (ES = 0.6-1.2) to large (ES = 1.2-2.0) increases in recovery durations were observed for both RSA and RHIA bouts as the number of efforts in the respective bouts increased. In comparison to RHIA bouts, larger recovery durations were observed in RSA bouts when sprint activity increased to 6 efforts per bout (11.4 ± 6.8%, ES = 1.2).

Insert Figure 3 About Here

Figure 4 shows the percentage change in recovery duration between RSA bouts and RHIA bouts for national and international matches, expressed relative to sets of 2 RSA or RHIA

exercise bouts. Very large differences in recovery durations between national and international matches were observed for RSA bouts involving 3 (23.5 ± 3.8%, ES = 2.33) and 4 (32.9 ± 5.8%, ES = 3.01) efforts, with national matches associated with greater recovery durations than international matches. Conversely, the recovery duration between RHIA efforts for international matches was greater than national matches for RHIA bouts involving 3 (14.5 ± 5.0%, ES = 2.15), 4 (11.8 ± 1.4%, ES = 1.21), and 5 (11.2 ± 1.7%, ES = 0.89) efforts.

Insert Figure 4 About Here

Discussion

This study investigated the repeated-sprinting and high-intensity exercise (e.g. striding and sprinting) demands of elite Women's soccer match-play. The number of repeated-sprint and repeated high-intensity exercise (i.e. striding and sprinting) bouts performed were similar between the first and second half of matches. While sprint duration tended to remain relatively stable, irrespective of the number of sprints in a repeated-sprint bout, or the period of play (i.e. first or second half of matches), recovery between sprints increased in the second half of matches, and when a greater number of efforts were performed per bout. These findings suggest that first to second half reductions in repeated high-intensity exercise activity and repeated-sprint activity do not occur in elite Women's soccer competition. However, players increase the amount of low-intensity recovery undertaken between repeated high-intensity exercise and repeated-sprint efforts, most likely in an attempt to maintain repeated high-intensity activity and repeated-sprint performance.

The results of this study demonstrate large individual variations in the repeated-sprint demands of elite Women's soccer match-play, with some players performing no repeated-sprint bouts, and others performing up to 23 repeated-sprint bouts in a match. While our sample size prevented a detailed analysis of the repeated-sprint and high-intensity activity demands of different playing positions, it is likely that this variability is explained by the different positional demands experienced in soccer. [5] The number of sprints also varied considerably, with as few as 2 sprints in a bout (53.5%), and as many as 7 sprints (0.6%) in a bout. The player with the single highest number of repeated-sprint bouts in a match performed 23 repeated-sprints bouts, of which 9 bouts involved 4 sprints, 6 bouts involved 5 sprints, 4 bouts involved 6 sprints, and 2 bouts involved as many as 7 sprints. These findings highlight the stochastic nature of Women's soccer, while also emphasizing the highly variable nature of repeated-sprint activity in this sport. Clearly, conditioning programs designed to improve repeated-sprint ability should focus on bouts with varying sprint frequencies and recovery durations that mimic the intense intermittent and unplanned nature of sprinting in the sport. Moreover, individualized and position-specific conditioning programs may be necessary for some players in order to adequately prepare them for the large amounts of repeated-sprint and repeated high-intensity activity required in competition.

We found that the average number of repeated-sprint bouts and mean sprint duration was maintained across the duration of the match, although consistent with previous studies of the high-intensity running demands of elite soccer, [1,3] the frequency of RSA and RHIA bouts in the first 15 minutes of the match tended to be higher than during other 15 minute periods. The finding of maintained repeated-sprint activity across the first and second half of matches in the present study is consistent with the results from male soccer players; sprinting performance was also maintained across the duration of a match, despite reductions in total distance covered and distances covered in high-speed running.[15] We also found that recovery

duration progressively increased with increases in the number of efforts performed per bout. In addition, while mean sprint duration was relatively stable from the first to the second half of the match, recovery durations between sprint efforts were longer in the second half. It has previously been shown that points scored or conceded in elite team sport competition occur in close proximity to a repeated effort bout, [8] suggesting that the ability (or inability) to perform repeated-sprint activity may prove critical to the outcome of the match. It is unclear if the increase in recovery durations in the second half of matches, and with greater sprint frequencies, observed in the present study represents conscious control by players. However, these results may suggest a pacing strategy employed by players in an attempt to preserve repeated-sprint performance. [16]

A novel aspect of this study was the expansion of previous repeated-sprint definitions to include repeated high-intensity exercise (i.e. striding and sprinting) activities, and repeated, successive (i.e. 2) sprints. Previous studies have defined repeated-sprint activity as 3 or more sprints, with short (≤20 s) recovery between sprints. [7] While this definition has provided a consistent method of assessing repeated-sprint ability, limiting repeated-sprint bouts to 3 or more sprints effectively eliminates successive, short-recovery sprints that may also be physically demanding but fail to meet the traditional (i.e. 3 or more sprints) repeated-sprint criteria. Equally, high-speed running (i.e. striding) efforts, which may also be separated by short recovery periods, are likely to make a substantial contribution to the energetic cost of competition, despite failing to qualify as repeated-sprint activity. Consistent with studies from other high-intensity intermittent team sports (e.g. water polo), [10] the number of repeated high-intensity efforts increased considerably when considering repeated-sprint bouts that only included 2 sprints. Furthermore, the number of repeated-effort bouts performed per player increased from 5.1 to 31.2, when considering repeated-striding and sprinting, rather than repeated-sprinting alone. However, rather than over-emphasizing the repeated-sprint demands of competition, we believe these findings provide a more complete picture of the repeated high-intensity effort activity that is required in elite Women's soccer match-play. These findings provide specific information for the design of conditioning programs to meet the repeated high-intensity exercise (i.e. striding and sprinting) demands of intermittent team sports. Importantly, these findings consider activities that are physically demanding, including those activities that do not involve sprinting.

In general, few differences were observed between national and international matches for the durations of sprinting efforts (in RSA bouts), sprinting and striding efforts (in RHIA bouts), and recovery between efforts (for both RSA and RHIA bouts). However, the average sprint duration was longer in international matches (2.32 ± 0.15 s *vs.* 1.83 ± 0.24 s) when RSA bouts consisted of 6 efforts, and the recovery duration between efforts was shorter in international matches (11.97 ± 4.09 s *vs.* 14.60 ± 4.18 s) when RSA bouts consisted of 4 efforts. Of interest was the percentage change in recovery duration between RSA and RHIA bouts for national and international matches when recovery durations were expressed relative to sets of 2 RSA and RHIA exercise bouts. RSA bouts involving 3 and 4 efforts were associated with greater recovery durations for national matches, while the recovery duration between RHIA efforts for international matches was greater than national matches for RHIA bouts involving 3, 4, and 5 efforts. While previous studies have investigated the physical demands of soccer match-play, reports on the relative importance of high-intensity running to soccer performance are equivocal, with some, [2,3] but not all [4,5] studies demonstrating that elite players perform more high-intensity running than sub-elite competitors, and when the demands of competition are greatest. Our results are generally consistent with the hypothesis that the RSA demands are similar between national and international competition, although in

international matches the absolute sprint durations are slightly longer and absolute recovery durations slightly shorter than national matches. Furthermore, in comparison to national matches, elite female soccer players have higher relative recovery durations between RHIA efforts in international matches, perhaps due to the relatively short recovery durations between RSA efforts.

In this study, the physical demands of national and international female soccer matches were assessed using video-based time-motion analysis. Due to the time-consuming and labour-intensive nature of this methodology, our sample size is limited. Consequently, while the RSA and RHIA demands tended to be greater in central mid-fielders, our ability to perform a comprehensive analysis and make definitive conclusions on the differences in RSA and RHIA among playing positions is restricted, and could be viewed as a limitation of this study. While the use of global position system (GPS) technology would permit a much larger study to be performed, including a detailed analysis of positional differences, current restrictions applied by the International Federation of Association Football (FIFA) preventing players from wearing microsensor technology in competition, may limit further progress in the field of repeated-sprint and repeated high-intensity exercise activity. In addition, while it has recently been shown that performance, physiological, and perceptual responses may be influenced by the magnitude of directional change performed during repeated-sprint bouts, [17] we made no attempt to quantify repeated change of direction activities. Although this decision may have resulted in an underestimation of the repeated sprint and high-intensity exercise demands of Women's soccer match-play, we reconciled this decision with the knowledge that the coding of our other match-play activities was highly reproducible.

In conclusion, this study investigated the repeated-sprinting and high-intensity exercise (e.g. striding and sprinting) demands of elite Women's soccer match-play. A major new finding of this study was the manner in which repeated-sprint and repeated high-intensity exercise (i.e. striding and sprinting) activity changed across the duration of a competitive match. When comparing the repeated-sprint and repeated high-intensity exercise demands of the first and second half, no differences were found for the number of repeated-sprint or repeated high-intensity exercise bouts performed. Furthermore, the recovery between repeated-sprint efforts increased from the first to the second half, while the recovery between repeated high-intensity exercise efforts remained relatively stable. These findings suggest that reductions in performance manifest in different ways for repeated-sprint and repeated high-intensity exercise ability. It appears that repeated-sprint activity is protected by decreasing the amount of repeated high-intensity exercise performed or by increasing the amount of low-intensity recovery activity undertaken between repeated-sprints.

Practical Applications

This study described the unique repeated high-intensity exercise demands of elite Women's soccer match-play. Repeated-sprint bouts involved as few as 2 sprint efforts, and as many as 7 sprint efforts. As the number of sprints performed per bout increased, the recovery durations between sprints also increased. Despite the intense nature of the repeated-sprint and repeated high-intensity exercise bouts, players were able to maintain repeated-effort performance over the duration of the match. These findings can be used by coaches to adequately prepare players for the repeated high-intensity (both striding and sprinting) demands of competition. Critically, these results emphasize the importance of repeated-sprint and effort ability to elite Women's soccer, and highlight the importance of training this quality to prevent reductions in performance during competitive match-play.

417 **References**

418 1. Mohr, M, Krustrup, P, Bangsbo, J. Fatigue in soccer: a brief review. *J. Sports. Sci.*
419 2005;23:593-599.
420 2. Mohr, M, Krustrup, P, Andersson, H, Kirkendal, D, Bangsbo, J. Match activities of elite
421 women soccer players at different performance levels. *J. Strength. Cond. Res.* 2008;22:341-
422 349.
423 3. Andersson, HA, Randers, MB, Heiner-Moller, A, Krustrup, P, Mohr, M. Elite female
424 soccer players perform more high-intensity running when playing in international games
425 compared with domestic league games. *J. Strength. Cond. Res.* 2010;24:912-919.
426 4. Rampinini, E, Impellizzeri, FM, Castagna, C, Coutts, AJ, Wisloff, U. Technical
427 performance during soccer matches of the Italian Serie A league: effect of fatigue and
428 competitive level. *J. Sci. Med. Sport.* 2009;12:227-233.
429 5. Di Salvo, V, Gregson, W, Atkinson, G, Tordoff, P, Drust, B. Analysis of high intensity
430 activity in Premier League soccer. *Int. J. Sports. Med.* 2009;30:205-212.
431 6. Gabbett, TJ, Mulvey, MJ. Time-motion analysis of small-sided training games and
432 competition in elite women soccer players. *J. Strength. Cond. Res.* 2008;22:543-552.
433 7. Spencer, M, Lawrence, S, Rechichi, C, Bishop, D, Goodman, C. Time-motion analysis of
434 elite field hockey, with special reference to repeated-sprint activity. *J. Sports. Sci.*
435 2004;22:843-850.
436 8. Austin, DJ, Gabbett, TJ, Jenkins, DG. Repeated high-intensity exercise in a professional
437 rugby league. *J. Strength. Cond. Res.* 2011;25:1898-1904.
438 9. Buchheit, M, Mendez-Villanueva, A, Simpson, BM, Pourdon, PC. Repeated-sprint
439 sequences during youth soccer matches. *Int. J. Sports. Med.* 2010;31:709-716.
440 10. D'Auria, S, Gabbett, T. A time-motion analysis of international women's water polo
441 match play. *Int. J. Sports. Physiol. Perform.* 2008;3:305-319.
442 11. Gabbett, TJ, Jenkins, DG, Abernethy, B. Physical demands of professional rugby league
443 training and competition using microtechnology. *J. Sci. Med. Sport.* 2012;15:80-86.
444 12. Tan, F, Polglaze, T, Dawson, B. Activity profiles and physical demands of elite women's
445 water polo match play. *J. Sports. Sci.* 2009;27:1095-1104.
446 13. Batterham, AM, Hopkins, WG. Making meaningful inferences about magnitudes. *Int. J.*
447 *Sports. Physiol. Perform.* 2006;1:50-57.
448 14. Gregson, W, Drust, B, Atkinson, G, Di Salvo, V. Match-to-match variability of high-
449 speed activities in Premier League soccer. *Int. J. Sports. Med.* 2010;31:237-242.
450 15. Weston, M, Drust, B, Gregson, W. Intensities of exercise during match-play in FA
451 Premier League referees and players. *J. Sports. Sci.* 2011;29:527-532.
452 16. Duffield, R, Coutts, AJ, Quinn, J. Core temperature responses and match running
453 performance during intermittent-sprint exercise competition in warm conditions. *J. Strength.*
454 *Cond. Res.* 2009;23:1238-1244.
455 17. Buchheit, M, Haydar, B, Ahmaidi, S. Repeated sprints with directional changes: do
456 angles matter? *J. Sports. Sci.* 2012; in press.

457

458 **FIGURE CAPTIONS**
459
460 **Figure 1.** Number of repeated-sprint and repeated high-intensity activity (i.e. sprinting and/or
461 striding) effort bouts when analyzed as sets of 2, 3, or 4+ efforts in 15 minute periods
462 throughout the game for national and international players. (A) repeated-sprint activity (RSA)
463 for national players; (B) repeated high-intensity activity (i.e. striding and/or sprinting, RHIA)
464 for national players; (C) repeated-sprint activity for international players; (D) repeated high-
465 intensity activity (i.e. striding and/or sprinting) for international players. Data are presented
466 as the mean number of RSA and RHIA bouts performed in each 15 minute period of the
467 match.
468
469 **Figure 2.** Comparison of first and second half recovery durations per bout for (A) repeated-
470 sprint, and (B) repeated high-intensity activity (i.e. striding and/or sprinting), when analyzed
471 as sets of 2, 3, 4, 5 or 6 efforts, with the recovery criteria being ≤20 s between efforts. Data
472 are mean ± SD. *Moderate effect size (ES = 0.6–1.2).
473
474 **Figure 3.** Comparison of mean recovery duration between repeated-sprint (RSA) and
475 repeated high-intensity activity (i.e. striding and/or sprinting; RHIA) bouts when analyzed as
476 sets of 2, 3, 4, 5 or 6 efforts, with the recovery criteria being ≤20 s between efforts. Data are
477 presented as percentage change from sets of 2 bouts (mean ± SD). *Moderate effect size (0.6–
478 1.2) between repeated-sprint and repeated high-intensity activity (i.e. striding and/or
479 sprinting); †Moderate and ‡Large effect size (1.2–2.0) between bout 2 and subsequent bouts
480 for repeated-sprint; ¤Moderate and §Large effect size between bout 2 and subsequent bouts
481 for repeated high-intensity activity (i.e. striding and/or sprinting).
482
483 **Figure 4.** Comparison of mean recovery duration for national and international players
484 between (A) repeated-sprint (RSA) and (B) repeated high-intensity activity (i.e. striding
485 and/or sprinting; RHIA) bouts when analyzed as sets of 2, 3, 4, 5 or 6 efforts, with the
486 recovery criteria being ≤20 s between efforts. Data are presented as percentage change from
487 sets of 2 bouts (mean ± SD). *Very large effect size (>2.0) between groups; †Large effect size
488 (1.2–2.0) between groups.
489

490 **Table 1.** Match-play activities used during time-motion analysis of women soccer players.

Match-play activity	Definition
Standing	No locomotor activity
Walking	Movement involves at least one foot being in continual contact with the ground
Jogging	Movement involves a flight phase and minimal arm swing
Striding	Movement is similar to jogging but involves a longer stride and more pronounced arm swing
Sprinting	Maximal effort with a greater extension of the lower leg during forward swing and higher heel lift relative to striding

491

Table 2. Number of repeated-sprint and repeated high-intensity activity (i.e. sprinting and/or striding) efforts per bout when analyzed as sets of 2, 3, 4, 5 or 6 efforts, with the recovery criteria being ≤20 s between efforts for national and international players.

Actions per bout	2	3	4	5	6
Sprint					
National					
No. per player/per game	5.3 ± 5.0	2.6 ± 2.8	1.2 ± 1.8	0.4 ± 0.8	0.1 ± 0.3
Sprint Duration (s)	2.21 ± 0.57	2.03 ± 0.49	2.30 ± 0.83	1.96 ± 0.52	1.83 ± 0.24[b]
Recovery Duration (s)	9.73 ± 4.93	13.64 ± 4.29	14.60 ± 4.18[a]	14.56 ± 2.22	15.92 ± 2.47
International					
No. per player/per game	4.9 ± 5.4	2.5 ± 3.4	1.1 ± 2.3	0.6 ± 1.6	0.4 ± 1.1
Sprint Duration (s)	2.35 ± 0.56	2.32 ± 0.66	2.12 ± 0.48	1.94 ± 0.56	2.32 ± 0.15
Recovery Duration (s)	10.22 ± 4.42	11.93 ± 4.67	11.97 ± 4.09	15.36 ± 5.99	17.22 ± 2.50
All Matches					
No. per player/per game	5.1 ± 5.1	2.5 ± 3.0[*]	1.1 ± 2.0[*]	0.5 ± 1.2[†‡]	0.2 ± 0.7[†‡]
Sprint Duration (s)	2.27 ± 0.56	2.16 ± 0.60	2.24 ± 0.77	1.96 ± 0.51	2.08 ± 0.19
Recovery Duration (s)	9.94 ± 4.73	12.95 ± 4.34[*]	13.28 ± 3.99[*]	15.11 ± 3.74[†]	16.57 ± 2.49[†‡§]
Sprint/Stride					
National					
No. per player/per game	34.4 ± 19.2	24.0 ± 16.9	19.5 ± 17.0	14.9 ± 14.1	12.0 ± 13.1
Sprint/Stride Duration (s)	3.05 ± 0.76	3.02 ± 0.84	3.05 ± 0.86	2.86 ± 0.75	2.96 ± 0.77
Recovery Duration (s)	9.55 ± 2.58	11.34 ± 2.99	12.78 ± 3.04	13.96 ± 2.76	14.76 ± 2.49
International					
No. per player/per game	27.3 ± 17.9	20.0 ± 16.1	14.8 ± 15.9	12.1 ± 15.0	9.9 ± 15.1
Sprint/Stride Duration (s)	2.98 ± 0.66	2.94 ± 0.72	2.98 ± 0.76	2.87 ± 0.65	2.93 ± 0.67
Recovery Duration (s)	9.42 ± 2.68	12.55 ± 3.08	13.72 ± 3.38	14.66 ± 3.16	14.70 ± 3.18
All Matches					
No. per player/per game	31.2 ± 18.7	22.2 ± 16.4[*]	17.4 ± 16.4[*]	13.7 ± 14.4[*]	11.1 ± 13.8[†‡]
Sprint/Stride Duration (s)	2.98 ± 0.66	2.94 ± 0.72	2.98 ± 0.76	2.87 ± 0.65	2.93 ± 0.67
Recovery Duration (s)	9.49 ± 2.60	11.86 ± 3.07[*]	13.21 ± 3.17[†]	14.23 ± 2.90[†‡]	14.74 ± 2.66[†‡]

Data are mean ± SD. [*]Moderate effect size (0.6–1.2) between bouts of 2 and subsequent bouts; [†]Large effect size (1.2–2.0) between bouts of 2 and subsequent bouts; [‡]Moderate effect size (0.6–1.2) between bouts of 3 and subsequent bouts; [§]Moderate effect size (0.6–1.2) between bouts of 4 and subsequent bouts. [a] Moderate effect size (0.6–1.2) between national and international players; [b] Very large effect size (>2.0) between national and international players.

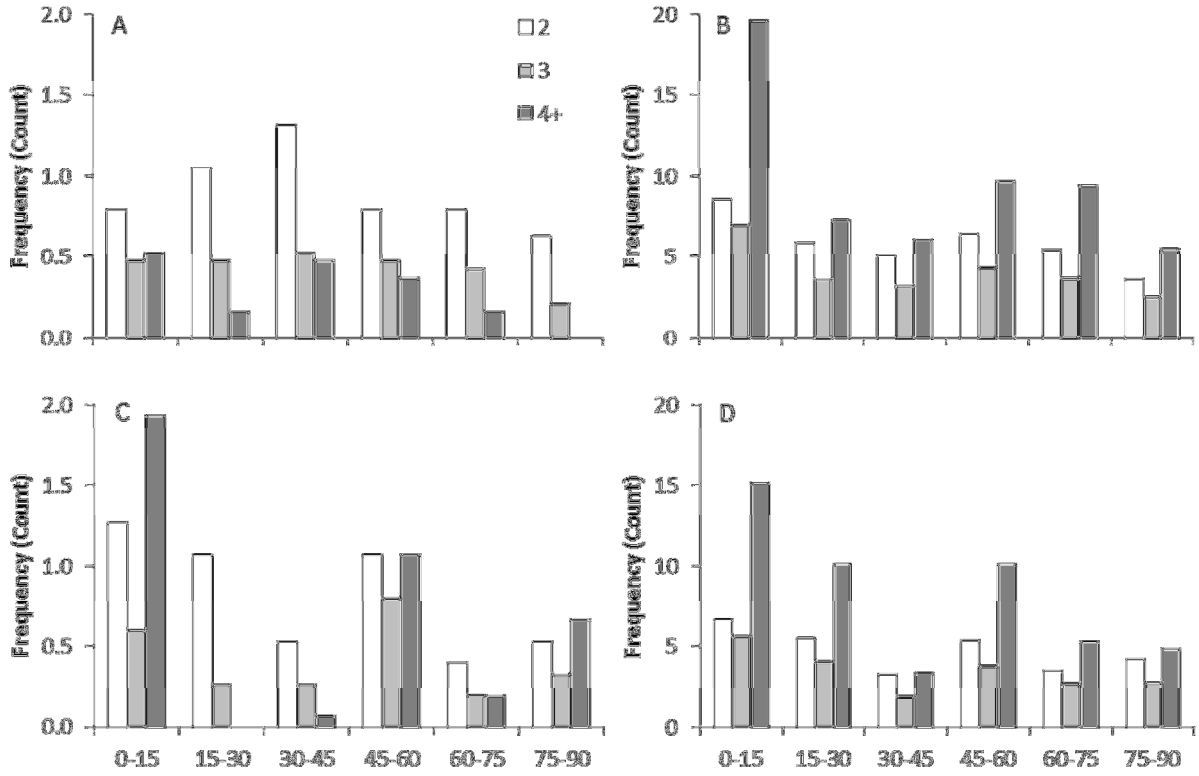


Figure 1.

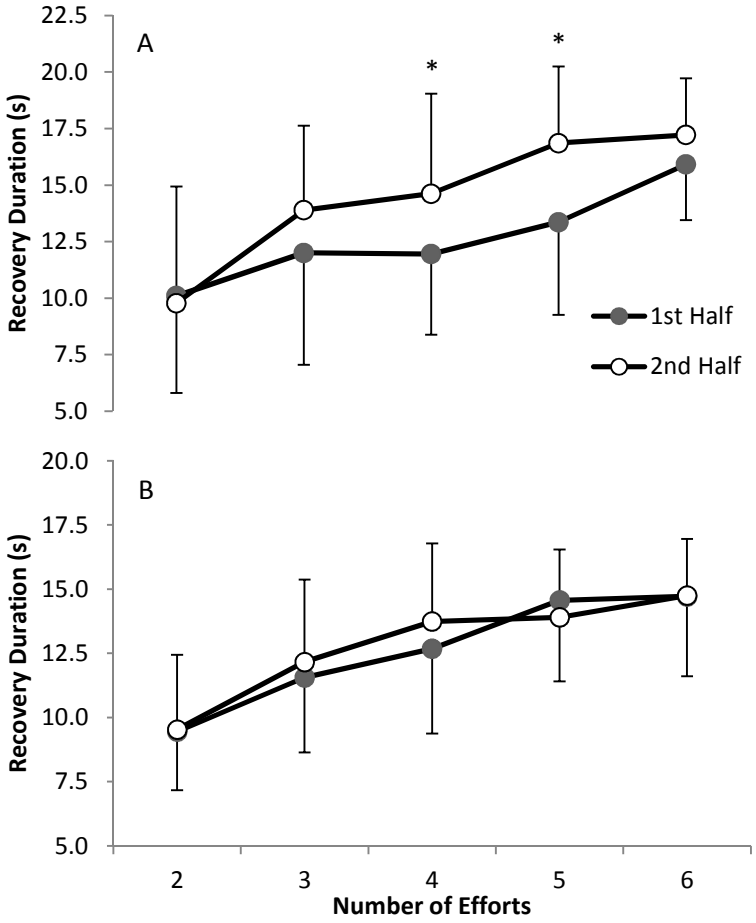

A
B
Recovery Duration (s)
Recovery Duration (s)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
*
*
1st Half
2nd Half
2
3
4
5
6
Number of Efforts

Figure 2.

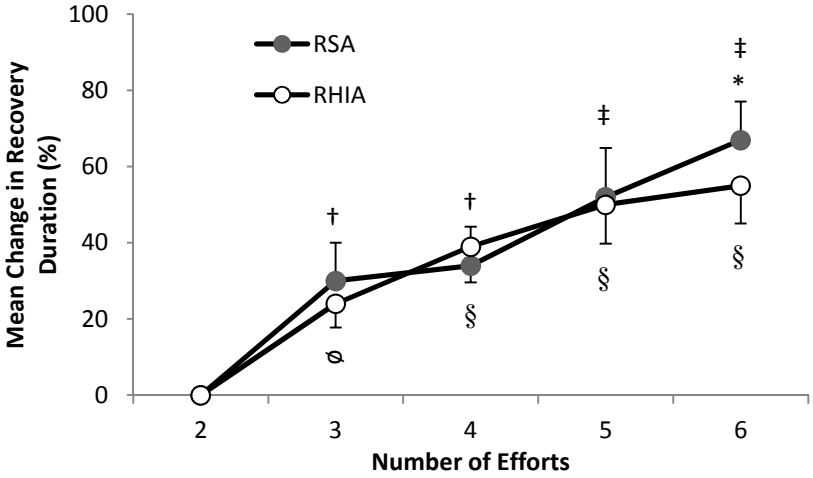
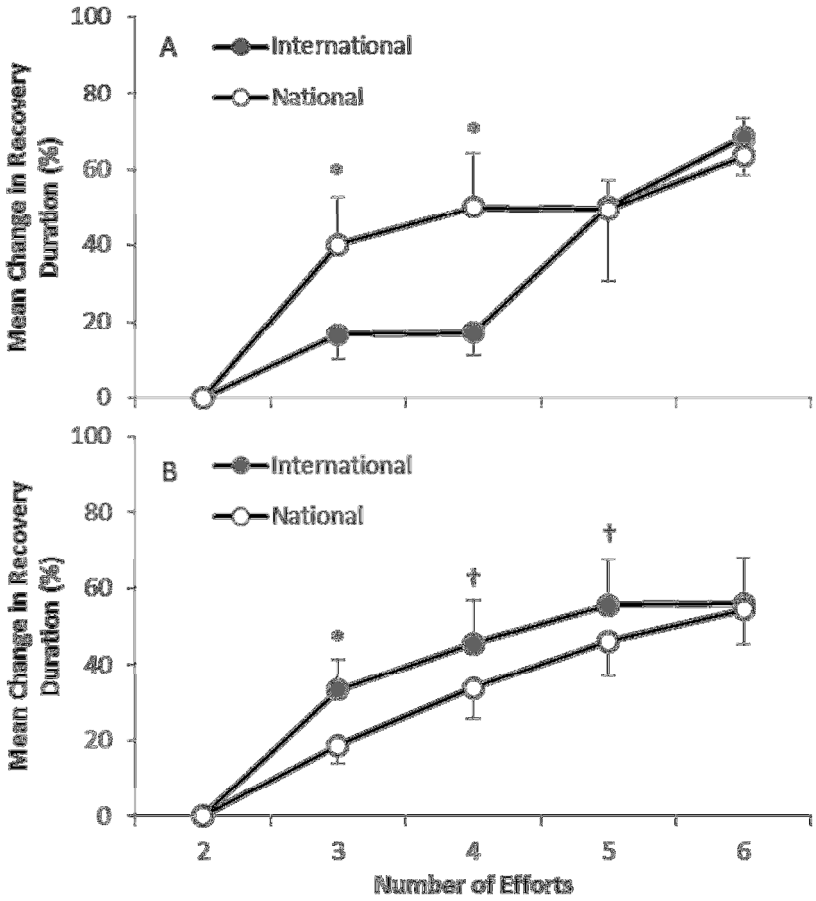

100
80
60
40
20
0
RSA
RHIA
Mean Change in Recovery Duration (%)
2
3
4
5
6
Number of Efforts
†
†
‡
‡
*
§
§
§
ø

Figure 3.

554



555
556
557 **Figure 4.**