Indian Journal of Science and Technology, Vol 9(43), DOI: 10.17485/ijst/2016/v9i43/105031, November 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Association between in-game Performance Parameters Recorded via Global Positioning System and Sports Injuries to the Lower Extremities in Elite Female Field Hockey Players

Tae-GyuKim[1], Jung-Hoon Cha[2] and Jong-Chul Park[3*]

[1]Department of Sports Medicine, Taeneung National Training Center of the Korean Olympic Committee, Nowon-gu, Seoul, Republic of Korea; Ktk7718@gmail.com
[2]Department of Community Sports, Korea National Sport University, Songpa-gu Seoul, Republic of Korea; jhcha8055@knsu.ac.kr
[3]Department of Sport Science, Korea Institute of Sport Science, Nowon-gu, Seoul, Republic of Korea; mori@sports.re.kr

Abstract

Objectives: We aimed to determine the potential association between in-game performance parameters recorded via Global Positioning System (GPS) and non-contact knee and ankle injuries in elite female field hockey athletes. **Methods/Statistical Analysis**: This study included 32 elite female field hockey players free from sports injuries of the knee and ankle joint. GPS tracking was used to record the distance covered while running at various speeds, time spent sprinting and maximum speed during all international competitions in which each player participated without experiencing pain. All injury events were recorded. Data were analyzed using descriptive statistics, the independent t-test and binary logistic regression. **Findings**: Low-intensity running distance was significantly higher in players who did not experience injury throughout the duration of the study (t = 2.182, p = 0.037). The risk for in-game knee injury decreased with increasing distance covered while running at low speed (Odds Ratio = 0.8; 95% Confidence Interval = 0.6-1.0; χ^2 = 3.964; p = 0.046). **Improvements/Applications**: These findings provide information useful for developing strategies for preventing sports-related injuries during field hockey competitions.

Keywords: Female Field Hockey Global Positioning System, Risk Factor, Sports Injury

1. Introduction

Injuries to the lower extremities are common in female field hockey players, accounting for over 50% of the total number of injuries during a game or practice session. Among[1] such injuries, ankle ligament sprain and internal derangement in the knee account for 13.7% to 15.0% and 7.8% to 10.2%, respectively. Previous[2] studies insisted that these higher rates of injury to the lower extremities were strongly related to higher running volumes. In[3,4] particular, in team sports such as field hockey, rugby and soccer, many players are far more likely to suffer sports injury to lower extremities because of the specific nature of the motion, which include short repeated sprints, rapid acceleration, deceleration and changes of direction[5–7].

During a match of elite team sports, a large amount of high-intensity running is required. Several[8] studies reported that players of female soccer and field hockey cover 9-12 km and perform 19-62 sprint bouts in a game. These[7,9,10] high-intensity activities were shown to occur

*Author for correspondence

more often during matches than during practices sessions and were associated with increased risk of sports injuries during the game. In[9,11,12] fact, reported that, during matches of female field hockey, the prevalence of sports injuries was approximately 7.87 injuries/1000 athlete-exposures, which was twice as high as during practice sessions.

It has been reported that, in female field hockey matches, injuries to the knee and ankle, respectively account for 23.1% and 9.1% of severe injuries (i.e. requiring over 10 days of recovery) and that a non-contact mechanism underlies both types of injury. These[2] severe injuries can impose substantial time and a significant financial burden on the team or the athletes and damage athletes impose su. Therefore[12,13], to prevent sports-related injuries, it is essential to monitor the in-game running load, which can be described in terms of parameters such as distance covered, maximal speed or high-intensity running[12,14].

Recently, Global Positioning System (GPS) technology has become widely used to analyze the physiological demands and quantify the external load of individual athletes during matches and training in intermittent running sports such as soccer, field hockey and rugby. A[9,12,14–17] previous study[16] reported that GPS units produce acceptable measurements of sprint distance and have good intra-unit reliability for total distance covered (Intraclass Correlation Coefficient, ICC = 0.51), low-speed running distance (ICC = 0.97) and high-speed running (ICC = 0.88). Therefore, in the present study, we aimed to determine the association between in-game performance parameters measured via GPS and the incidence of non-contact injury to the knee or ankle in elite athletes, in an effort, to provide information necessary for developing strategies for preventing sports-related injuries in field hockey athletes.

2. Methodology

2.1 Subjects

This study included 32 elite players registered in the Korean national team of female field hockey. Goalkeeper was excluded. All players were competing in international competitions and were free from pain and disability of the knee and ankle joints at the commencement of this study. Each player was informed with respect to protocol of the study and signed a written informed consent form to participate in the study.

2.2 GPS-Measured Parameters of In-game Performance

AGPS (GPSports, SPI-HPU 5 Hz (interpolated 15 Hz), Canberra, Australia) was used to record the speed and position of each player during the matches. The GPS units were located at the T2-T6 level of the spinal column and secured in place with a harness[17].

The following in-game performance parameters were recorded and analyzed. Sprint, which was defined as running at a velocity of above 19.0 km/h was stratified into 3 categories depending on the duration of the sprinting bouts: Low-duration bouts (below 6 seconds), moderate-duration bouts (6-10 seconds) and high-duration bouts (above 10 seconds). Total[17] distance covered, which represents an overall assessment of the player's activity in a given match, was stratified into 5 movement velocity bands[6,17]; very low-intensity (below 6 km/h), low-intensity (6-12 km/h), moderate-intensity (12-14 km/h), high-intensity (18-24 km/h) and very high-intensity (above 24 km/h).

For each player, data was collected during all international competitions matches that the player participated in between the commencement of the study and the moment of the first injuries to the knee or ankle joint. An injury was defined as any non-contact injury associated with pain, swelling, tenderness or discomfort in the knee or ankle joint. If an injured player continued to participate in the competition, the data collected during the matches that took place after occurrence of the first symptoms of knee or ankle joint injury were excluded from the analysis.

2.3 Statistical Analysis

Descriptive statistics were expressed as mean ± standard deviation and frequencies. The independent t-test was used for comparing the GPS-measured in-game performance data between players who experienced injury and those who did not. Binary logistic regression was used to identify the relationship between the GPS-measured data and the incidence of injury to the knee or ankle joint. All levels of statistical significance were set at $\alpha = 0.05$. All analyses were performed using SPSS for Windows version 19.0 (IBM, Armonk, NY, USA).

3. Results and Discussions

The study included 32 elite female field hockey players (11 defenders, 9 midfielders and 12 forwards; age, 28.16±3.14 years; height, 164.94±4.19 cm; weight, 59.59±4.17 kg; experience in field hockey, 15.31±4.43 years). Each player participated in 3 to 20 international competitions.

3.1 GPS-measured Performance Parameters for Players with Injury to the Knee or Ankle

Of the 32 players included in the study, 15 (46.9%) and 14 (43.8%) players experienced in-game injuries to the ankle and the knee joint, respectively, whereas the remaining 3 (12.5%) players had no injury to either the ankle or knee joint.

Table 1 provides an overview of the distance covered at various running speeds in players with different injury status and location. Compared to players who experienced injury to the ankle joint, those who did not experience such injury tended to cover a higher distance at all but one running speed (low-intensity), but this tendency was not statistically significant. On the other hand, the opposite was found with respect to injury to the knee joint; specifically, players who did not experience injury to the knee joint covered less distance at all but one running speed (low-intensity) than did those who did experience such injury; moreover, the low-intensity running distance was significantly higher for players who did not experience knee injury (2032.24±335.92 m vs. 1919.82±286.42 in players who experienced knee injury; t = 2.182, p = 0.037).

It is important to note that, for team sports, the distance covered during the match may differ significantly from that covered during training session, both for the team and for the individual players[18]. In[9,17] reported that female field hockey players may cover 6,154-6,931 m and 5,541 m, respectively, over the course of the match. Similarly[19] mentioned that female field hockey players of National Collegiate Athletic Association Division I universities covered 6,062-6,765 m. These figures are higher than those noted in the present study (5,170-5,358 m) and the difference in distance is likely related to differences in factors such as nationality, team location, world ranking and age. However[19,20], total distance covered may include activities on the bench. Therefore, relative distance, defined as distance covered per minute, may be a more suitable indicator of relevant player activity, to minimize the margin of error and provide a more accurate reflection of the intensity of the match. Further[18] studies providing information on the relative distance are warranted, to assess the difference between teams or individuals participating in team sports.

Table 1. In-game distance covered by elite female field hockey players running at various speeds

Injury (n, %)			Total distance covered	Very low-intensity	Low-intensity	Moderate-intensity	High-intensity	Very high-intensity
Ankle	Injured	15 (46.9)	5169.96 ?00.97	1477.68 ?08.76	1995.13 ?55.07	569.89 ?20.33	764.08 ?70.09	363.48 ?1.09
	Non-injured	17 (53.1)	5357.62 ?95.97	1636.33 ?89.21	1972.41 ?86.70	588.91 ?34.05	782.53 ?67.63	377.42 ?8.54
Knee	Injured	14 (43.8)	5282.06 ?31.79	1594.42 ?79.03	1919.82* ?86.42	590.47 ?46.75	797.09 ?77.07	380.24 ?5.31
	Non-injured	18 (56.2)	5260.01 ?70.80	1536.73 ?55.60	2032.24 ?35.92	571.85 ?11.25	755.84 ?60.21	363.61 ?0.86

Values are mean□tandard deviation unless otherwise specified. Distance expressed in units of meters.
*: $p<0.05$ in the independent t-test
Additional explanations: All players were injury- and pain-free at the commencement of the study. For each player, only data collected during the matches that took place between the commencement of the study and occurrence of the first injury to the knee or ankle. Non-injured refers to players who did not experience the respective injury over the course of the study period. Running speed was classified as: Very low-intensity, below 6 km/h; low-intensity, 6-12 km/h; moderate-intensity, 12-14 km/h; high-intensity, 18-24 km/h; very high-intensity, above 24 km/h

For team sports, the definition of velocity bands and movement patterns are needed to facilitate precise comparison and analysis of performance between players, teams and levels of competition[18]. In[9] mentioned that female field hockey players in Australia covered 3,017-3,618 m at 3-5 m/s in international competitions, while our present study showed that Korean hockey players covered 1,920-2,032 m while running at low speed and 570-590 m while running at moderate speed. To facilitate comparison between different reports regarding female field sports, it is necessary to distinguish between running and sprinting[14].

Table 2 provides an overview of the in-game sprint characteristics (maximum speed, sprint distance and number of sprint bouts with low, moderate or high duration) in players with different injury status and location. Compared to players who experienced injury to the ankle joint, those who did not experience such injury tended to have higher sprint distance and number of sprint bouts, but this tendency was not statistically significant. On the other hand, players who experienced injury to the knee joint tended to have higher sprint distance and number of sprint bouts (except for low-duration sprints) than did players who did not experience such injury, but this tendency was not significant either. The maximum speed of players who experienced ankle joint injury was higher than that of players who did not experience such injury, while the maximum speed of players who did not experience injury to the knee was higher than that of players who did experience such injury.

High-intensity running and sprint bouts can be critical to match results and[7] the sprint characteristics are related to performance levels in elite players of field sports. Furthermore[21], the ability to sprint faster is a characteristic that distinguishes top-class from lower-level players[14,22]. In[9] mentioned that the number of in-game sprint bouts was 43-58 in female field hockey players, while our present study showed that Korean hockey players performed 27-28 sprint bouts. In[17] showed the distance covered by high-intensity running and sprinting was 835 m and 232 m, respectively, while the present study reported a sprint distance of 356-365 m. These differences among countries are related to the discrepancy in the activity patterns and playing positions[17].

3.2 Association between In-Game Performance Parameters Measured via GPS and Incidence of In-Game Non-Impact Injury to the Ankle or Knee Joints

Table 3 shows the results of the binary logistic regression analysis for risk of ankle injury, involving 12 in-game performance parameters recorded via GPS. For every one unit increase in low-intensity distance and maximum speed, the risk for in-game ankle injury is expected to increase by approximately 1.2 times (Odds Ratio [OR],

Table 2. In-game sprint characteristics for elite female field hockey players

Injury (n, %)			Sprint distance (meter)	Sprint bouts (reps)	Low-duration bouts (reps)	Moderate-duration bouts (reps)	High-duration bouts (reps)	Maximum Speed (km/h)
Ankle	Injured	15 (46.9)	357.42 ?2.06	27.99 ?.83	24.96 ?.10	2.62 ?.11	0.23 ?.16	27.25 ?.24
	Non-injured	17 (53.1)	362.04 ?4.48	28.58 ?.95	25.44 ?.72	2.78 ?.82	0.24 ?.15	26.95 ?.90
Knee	Injured	14 (43.8)	365.43 ?9.80	28.45 ?.27	25.22 ?.91	2.85 ?.86	0.25 ?.16	26.92 ?.87
	Non-injured	18 (56.2)	355.56 ?3.68	28.19 ?.35	25.22 ?.77	2.59 ?.03	0.23 ?.15	27.23 ?.20

Values are mean tandard deviation unless otherwise specified.
Additional explanations: All players were injury- and pain-free at the commencement of the study. For each player, only data collected during the matches that took place between the commencement of the study and occurrence of the first injury to the knee or ankle. Non-injured refers to players who did not experience the respective injury over the course of the study period. Sprint bouts were classified as: Low-duration bouts, below 6 seconds; moderate-duration bouts, 6-10 seconds; high-duration bouts, above 10 seconds.

1.2; 95% Confidence Interval [CI]: 0.9-1.6) and 1.3 times (OR, 1.3; 95% CI: 0.7-2.6), respectively. However, with each additional bout of moderate- and high-duration, the risk for in-game ankle injury is expected to decrease by approximately 0.8 times (OR, 0.8; 95% CI: 0.4-1.8) and 0.7 times (OR, 0.7; 95% CI: 0.2-1.2), respectively. However, no variables were significantly associated with sports-related ankle injury.

Table 4 shows the results of the binary logistic regression analysis for risk of knee injury, involving 12 in-game performance parameters recorded via GPS. For every one unit increase in low-intensity distance and maximum speed, the risk for in-game knee injury is expected to decrease by approximately 0.8 times (OR, 0.8; 95% CI: 0.6-1.0) and 0.8 times (OR, 0.8; 95% CI: 0.4-1.5), respectively. Of the 12 performance parameters included, low-intensity distance was a significant risk factor (χ^2 = 3.964, p = 0.046). With each additional unit in the other variables, the risk for knee injury is expected to increase slightly, but no variable showed significant association with sports-related knee injury.

The most common field hockey injuries are lower limb sprains and contusions and it is important to prevent injuries by identifying the risk factors. Up[23] to now, previous studies on the risk factors for sports-related injuries in athletes of team sports identified internal (e.g. age, gender, body composition and anatomy) and external risk factors (e.g. use of protective equipment, environment), but not related to activity patterns. Therefore[1,23–27], the present study aimed to identify the risk factors for non-contact injuries to the ankle and knee joints for elite female field hockey players by analyzing the GPS-recorded activity patterns during the competitions. However, some researchers insisted that the distance covered and speed characteristics of team sports players are influenced by the positional differences. Furthermore[18,28,29], the excessive amount of training to a higher extent than the individual's exercise tolerance and capability, may carry a significantly higher risk for soft tissue injuries. Further[9,30] GPS-based studies on the risk factors of sports injuries should include the playing position and the relative value considering the individual training loads.

Table 3. Association between in-game performance parameters measured via GPS and incidence of non-impact injury to the ankle joint in elite female field hockey players

Variables	â	SE	Wald's χ^2	*p*-value	OR	95% IC	
Distance covered	0.0	0.001	0.690	0.406	1.000	0.998	1.001
Very low-intensity	-0.103	0.089	1.340	0.247	0.902	0.758	1.074
Low-intensity	0.204	0.129	2.522	0.112	1.227	0.953	1.578
Moderate-intensity	0.007	0.256	0.001	0.978	1.007	0.610	1.663
High-intensity	0.040	0.159	0.064	0.800	1.041	0.763	1.421
Very high-intensity	-0.053	0.293	0.032	0.857	0.949	0.534	1.685
Sprint distance	-0.001	0.005	0.033	0.857	0.999	0.989	1.009
Sprint bouts	-0.018	0.062	0.084	0.771	0.982	0.870	1.109
Low-duration bouts	-0.018	0.068	0.067	0.795	0.983	0.860	1.122
Moderate-duration bouts	-0.192	0.384	0.250	0.617	0.825	0.389	1.752
High-duration bouts	-0.400	2.282	0.031	0.861	0.670	0.228	1.178
Max Speed	0.270	0.344	0.614	0.433	1.310	0.667	2.572

Abbreviations: GPS: Global Positioning System; OR, Odds Ratio; CI, Confidence Interval; SE, Standard Error.
Additional explanations: All players were injury- and pain-free at the commencement of the study. For each player, only data collected during the matches that took place between the commencement of the study and occurrence of the first injury to the knee or ankle. Non-injured refers to players who did not experience the respective injury over the course of the study period. Running speed was classified as: Very low-intensity, below 6 km/h; low-intensity, 6-12 km/h; moderate-intensity, 12-14 km/h; high-intensity, 18-24 km/h; very high-intensity, above 24 km/h. Distance covered is given for each running speed. Sprint bouts were classified as: Low-duration bouts, below 6 seconds; moderate-duration bouts, 6-10 seconds; high-duration bouts, above 10 seconds.

Table 4. Association between in-game performance parameters measured via GPS and incidence of non-impact injury to the knee joint in elite female field hockey players

Variables	â	SE	Wald's χ^2	*p*-value	OR	95% IC	
Distance covered	0.0	0.001	0.010	0.922	1.000	0.999	1.001
Very low-intensity	0.054	0.082	0.430	0.512	1.055	0.899	1.238
Low-intensity	-0.278	0.139	3.964	0.046	0.758	0.577	0.996
Moderate-intensity	0.138	0.261	0.280	0.597	1.148	0.689	1.913
High-intensity	0.121	0.163	0.558	0.455	1.129	0.821	1.553
Very high-intensity	0.226	0.302	0.560	0.454	1.254	0.693	2.268
Sprint distance	0.002	0.005	0.146	0.702	1.002	0.992	1.012
Sprint bouts	0.008	0.062	0.016	0.899	1.008	0.892	1.139
Low-duration bouts	0.0	0.068	0.0	0.997	1.000	0.876	1.143
Moderate-duration bouts	0.285	0.384	0.550	0.458	1.329	0.626	2.822
High-duration bouts	0.923	2.296	0.162	0.688	2.516	0.028	2.822
Max Speed	-0.287	0.348	0.680	0.410	0.751	0.380	1.484

Abbreviations: GPS: Global Positioning System; OR, Odds Ratio; CI, Confidence Interval; SE, Standard Error

Additional explanations: All players were injury- and pain-free at the commencement of the study. For each player, only data collected during the matches that took place between the commencement of the study and occurrence of the first injury to the knee or ankle. Non-injured refers to players who did not experience the respective injury over the course of the study period. Running speed was classified as: Very low-intensity, below 6 km/h; low-intensity, 6-12 km/h; moderate-intensity, 12-14 km/h; high-intensity, 18-24 km/h; very high-intensity, above 24 km/h. Distance covered is given for each running speed. Sprint bouts were classified as: Low-duration bouts, below 6 seconds; moderate-duration bouts, 6-10 seconds; high-duration bouts, above 10 seconds.

4. Conclusion

This study investigated the relationship between in-game performance parameters measured via GPS and the incidence of non-contact injury to the knee or ankle in elite female field hockey players. The results of this study demonstrated that in female field hockey players, only low-intensity running distance is significantly higher among players who do not experience injury and that the risk for in-game knee injury decreases with increasing distance covered while running at low speed. These findings provide information useful for developing strategies for preventing sports-related injuries during field hockey competitions.

5. References

1. Murtaugh K. Injury patterns among female field hockey players. Medicine and Science in Sports and Exercise. 2001; 33(2):201–7.
2. Dick R, Hootman JM, Agel J, Vela L, Marshall SW, Messina R. Descriptive epidemiology of collegiate women's field hockey injuries: National Collegiate Athletic Association Injury Surveillance System. 1988-1989 through 2002-2003. Journal of Athletic Training. 2007; 42(2):211–20.
3. Vleck VE, Bentley DJ, Millet GP, Cochrane T. Triathlon event distance specialization: Training and injury effects. Journal of Strength and Conditioning Research. 2010; 24(1):30–6.
4. Wilson F, Gissane C, Gormley J, Simms C. A 12-month prospective cohort study of injury in international rowers. British Journal of Sports Medicine. 2010; 44:207–14.
5. Gabbett TJ. Science of Rugby League Football: A review. Journal of Sports Sciences. 2005; 23(9):961–76.
6. Gabbett TJ, Ullah S. Relationship between running loads and soft-tissue injury in elite team sport athletes. Journal of Strength and Conditioning Research. 2012; 26(4):953–60.
7. Spencer M, Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. Sports Medicine. 2005; 35(12):1025–44.

8. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. Journal of Sports Sciences. 2003; 21(7):519–28.
9. Gabbett TJ. GPS analysis of elite woman's field hockey training and competition. Journal of Strength and Conditioning Research. 2010; 24(5):1321–24.
10. Gabbett TJ, Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women soccer players. Journal of Strength and Conditioning Research. 2008; 22(2):543–52.
11. Dellal A, Lago-Penas C, Rey E, Chamari K, Orhant E. The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. British Journal of Sports Medicine. 2013; 49(6):390–4.
12. Ehrmann FE, Duncan CS, Sindhusake D, Franzsen WN, Greene DA. GPS and injury prevention in professional soccer. Journal of Strength and Conditioning Research. 2016; 30(2):360–7.
13. Knowles SB, Marshall SW, Miller T, Spicer R, Bowling JM, Loomis D, Millikan RW, Yang J, Mueller FO. Cost of injuries from a prospective cohort study of North Carolina High School Athletes. Injury Prevention. 2007; 13(6):416–21.
14. Hodun M, Clarke R, De Ste Croix M, Hughes J. Global Positioning System analysis of running performance in female field sports: A review of the literature. Strength and Conditioning Journal. 2016; 38(2):49–56.
15. Dwyer DB, Gabbett TJ. Global Positioning System data analysis: Velocity ranges and a new definition of sprinting for field sport athletes. Journal of Strength and Conditioning Research. 2012; 26(3):818–24.
16. Kelly VG, Scott MTU, Scott TJU. The validity and reliability of Global Positioning Systems in team sport: A brief review. Journal of Australian Strength and Conditioning. 2014; 22(5):186–90.
17. Macutkiewicz D, Sunderland C. The use of GPS to evaluate activity profiles of elite women hockey players during match-play 2011. Journal of Sports Sciences. 2011; 29(9):967–73.
18. Cummins C, Orr R, O'Connor H, West C. Global Positioning Systems (GPS) and microtechnology sensors in team sports: A systematic review. Sports Medicine. 2013; 43(10):1025–42.
19. Vescovi JD, Frayne DH. Motion characteristics of Division I college field hockey: Female Athletes in Motion (FAiM) study. Int J Sports Physiol Perform. 2015; 10(4):476–81.
20. White AD, MacFarlane NG. Contextual effects on activity profiles of domestic field hockey during competition and training. Human Movement Science. 2015; 40:422–31.
21. Andersson HA, Randers MB, Heiner-Moller A, Krustrup P, Mohr M. Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. Journal of Strength and Conditioning Research. 2010; 24(4):912–9.
22. Mohr M, Krustrup P, Andersson H, Kirkendal D, Bangsbo J. Match activities of elite women soccer players at different performance levels. Journal of Strength and Conditioning Research. 2008; 22(2):341–9.
23. Murtaugh K. Field hockey injuries. Current Sports Medicine Reports. 2009; 8(5):267–72.
24. Dvorak J, Junge A, Chomiak J, Graf-Baumann T, Peterson L, Rosch D, Hodgson R. Risk factor analysis for injuries in football players: Possibilities for a prevention program. American Journal of Sports Medicine. 2000; 28(5):S69–74.
25. Murphy DF, Connolly DAJ, Beynnon BD. Risk factors for lower extremity injury: A review of the literature. British Journal of Sports Medicine. 2003; 37(3):13–29.
26. Nilstad A, Andersen TE, Bahr R, HolmeI, Steffen K. Risk factors for lower extremity injuries in elite female soccer players. American Journal of Sports Medicine. 2014; 42(4):940–8.
27. Orooj M, Nuhmani S, Muaidi Q. Common injuries in field hockey. Saudi Journal of Sports Medicine. 2016; 16(1):20–7.
28. Waldron M. Twist C, Highton J, Worsfold P, Daniels M. Movement and physiological match demands of elite rugby league using portable Global Positioning Systems. Journal of Sports Sciences. 2011; 29(11):1223–30.
29. Kim TG, Park JC. Relationship between balance and isokinetic strength of ankle joint by playing position of elite female field hockey players. Indian Journal of Science and Technology. 2015; 8(19):1–6.
30. Piggott BG, McGuigan MR, Newton MJ. Relationship between physical capacity and match performance in semi-professional Australian rules football. Journal of Strength and Conditioning Research. 2015; 29(2):478–82.