Activity Profiles of International Goalball Players Using Wearable Devices

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Objective: To examine the activity profiles of international goalball players and individual player profiles using wearable devices.

Materials: All participants were Japanese national goalball players. Nine players were male (age: 24.7 ± 5.9 years, height: 169.1 ± 0.06 cm, weight: 73.1 ± 10.0 kg) and 5 were female (age: 20.8 ± 7.1 years, height: 158.2 ± 0.06 cm, weight: 55.6 ± 7.2 kg).

Methods: Measured items were PlayerLoad™, acceleration, deceleration, change of direction, and heart rate responses. Inertial measurement units (IMU) and heart rate sensors were embedded in the wearable device used by participants. Each player’s highest PlayerLoad™ value in a 10-sequence interval was referred to as the "peak value", and the average 10-sequence interval value after the peak was expressed as “post value”. Percentage of HRmax (%HRmax) observed in one playing time was also assessed.

Results: In male players, an approximately 50% decline in the mean PlayerLoad™ value was observed (from peak to post). The same tendency was observed in the female players, although the amount of decline was not that high. In male players, 80%-90% HRmax was observed in approximately 60% of a game, whereas that of female players was 30%. Furthermore, in female players, 70%-80% HRmax was observed in approximately 50% of a game, whereas that of male players was 30%.

Conclusions: The results provide scientific evidence for constructing a useful measurement tool when planning trainings for goalball players to improve their competitiveness.

Key words: Goalball, IMU (inertial measurement units), PlayerLoad™

Introduction

Goalball is a Paralympics goal-type sport for visually impaired and blind people[1]. Each team throws a ball with an embedded bell to each other aiming at scoring goals. The game requires players to have sensitive senses, other than sight, to grasp the game situations by sounds of the ball rolling and opponents’ movement, calls from fellow players, vibration of the floor, and lines’ touch[2]. In 1992, the international guideline of goalball[3] was translated into Japanese by the Japanese Para-Sports Association, and the sport was introduced in Japan. Since then, many people have made an effort to spread the sport and to develop athletes, for example, by holding goalball classes at sports centers for disabled individuals at various districts[4]. Under such a situation, since 2004, the national female goalball team of Japan has participated in Paralympics and won a gold medal in 2012 in London. Moreover, the male Japanese national team will participate in the Tokyo Paralympics in 2020 for the first time[4]. The Japan Goalball Association focuses on further strengthening the Japanese goalball athletes[5]. However, there are few studies on training and strengthening of goalball players. For
the Japanese national goalball team, it should be important to accumulate beneficial evidences and to train athletes based on these scientific evidences to win medals in the upcoming Paralympics.

Recently, the importance of information acquired from actual games has been emphasized to improve competitiveness of goal-type sports. Under such a circumstance, an indicator calculated using wearable inertial measurement units (IMU) called PlayerLoad™ has gained attention. PlayerLoad™ is an accelerometer-derived measurement of external physical loading that calculates instantaneous rate of change in acceleration, which is not an indicator based on moving distance or velocity. In research on goal-type sports for improving competitiveness, exercise intensity was generally calculated from moving velocity during the game. However, this method is problematic because a sport with slow velocity but with high physical load can be underestimated. In goalball, characterized by short acceleration and deceleration and continuous movements of standing up and diving, it cannot necessarily be interpreted that long-distance movement or high-speed velocity are better. Therefore, the indicator PlayerLoad™ using IMU, which is not based on moving distance and velocity, is thought to be suitable for calculating unique movements of goalball and to objectify physical load. Moreover, it should be undoubtedly meaningful to objectify players’ activities during games to improve competitiveness, especially for goalball athletes with difficulty utilizing visual images of games. Furthermore, the objective index can enable instructors to plan scientific-based training. Therefore, we aimed to examine the activity profiles of international goalball players and individual player profiles using wearable devices. The current study is the very first investigation to measure and analyze goalball players’ activity profile using wearable devices to improve sport competitiveness.

Methods

1. Participants

All participants were Japanese national goalball players. Nine players were male (age: 24.7 ± 5.9 years, height: 169.1 ± 0.06 cm, weight: 73.1 ± 10.0 kg) and 5 were female (age: 20.8 ± 7.1 years, height: 158.2 ± 0.06 cm, weight: 55.6 ± 7.2 kg). Prior to conducting the current study, we obtained approval from the ethics committee of the Faculty of Health and Sports Science in Juntendo University and informed consent was obtained from the study participants.

2. Measurement and items

1) Target games for analyses

There were 2 target games for analyses. One game for each female and male players. The women’s game was played in March 10, 2018, at Wayo Women’s University, and that for men was played in March 25, 2018, at the Minato City Sport Center located in Tokyo. Both games were played in gymnasiums. Each team per game comprised six players, who were selected by the team staff. The researchers were not involved in selecting the players. Each game had 12-minute halves, with a total of 24 minutes of playing time, and a 3-minute break between each half. No member changes were done in the games: all players played for 24 minutes in each game.

2) Measurement of activity profiles during the games

PlayerLoad™, high intensity events (HIE), acceleration (Acc), deceleration (Dec), change of direction (CoDs), and heart rate (HR) responses were measured to obtain the players’ activity profiles. IMU and HR sensor (Polar T31) embedded in the wearable device were developed by Catapult Sports, Australia. Accelerometers, gyroscopes, and magnetometers were built in the IMU used in the current study, which was capable of recording data at 100 Hz. By combining the obtained information, we could detect the inclination and direction. Thus, it was possible to measure not only the acceleration and deceleration frequencies but also the right and left movement frequencies. Players placed the device in the pocket located between the shoulder blades in the custom-made vest. In Additionally, all players wore the vest under the uniform.

PlayerLoad™ is an accelerometer-derived measurement of external physical loading that calculates instantaneous rate of change in acceleration for the x-, y-, and z-axes, sampling at 100 Hz. The mean score of each player’s highest PlayerLoad™ during a 10-sequence interval was referred to as “peak”, and the average 10-sequence interval after the peak was termed as “post”. HIE was defined in

Ikeda, et al: Activity profiles of international goalball players

280
accordance with Luteberget and Spencer’s definition\textsuperscript{6}, and sequence was defined according to Marato et al.’s definition\textsuperscript{11}. Each player’s individual maximum HR (HRmax) value was estimated using an age-predicted formula: 220 – age. Mean HR during the games was expressed as percentage of HRmax (%HRmax).

3. Statistical analysis

Results are presented as mean ± SD. Differences between the first and second halves were determined using Student’s paired t-test. Differences between the sexes were analyzed with Student’s unpaired t-test. Statistical significance was inferred for p < 0.05.

Results

1. Physical characteristics and activity profiles of goalball players

Table-1 shows the physical characteristics and activity profiles of 9 national male and 5 national female players from Japan. The total PlayerLoad\textsuperscript{TM} of the male and female players was 150.6 ± 19.3 (range: 124–186 and 126.6 ± 32.2 (range: 75–157), respectively. Mean HR of the male and female players was 154.8 ± 4.9 bpm (range: 145.1–161.7 bpm) and 153 ± 6.9 bpm (range: 144.7–160.6 bpm), respectively. The data acquired from one female player was not adapted because of the device defect.

2. PlayerLoad\textsuperscript{TM} during the first and second halves and whole game in both male and female games

Figure-1 shows PlayerLoad\textsuperscript{TM} in each sequence during the first and second halves and whole game in both men and women. For male players, mean PlayerLoad\textsuperscript{TM} in each sequence during the first and second halves and whole game were 7.32 ± 0.78, 7.45 ± 0.91, and 7.38 ± 0.80, respectively, whereas those for the female players were 6.47 ± 1.52, 5.90 ± 1.61, and 6.20 ± 1.56, respectively. Significant

### Table-1 Physical characteristics and activity profiles of goalball athletes

| Position | Athlete | Age (yrs) | Height (m) | Body mass (kg) | BMI (kg/m\textsuperscript{2}) | Total PL (a.u.) | HIE (n) | Acc (n) | Dec (n) | CoDs (n) | Mean HR (bpm) |
|----------|---------|-----------|------------|----------------|----------------|----------------|---------|---------|---------|----------|---------------|
| Male players | 1 Center | 27 | 1.68 | 70 | 24.8 | 129 | 30 | 13 | 16 | 97 | 152.8 |
| | 2 Center | 17 | 1.68 | 70 | 24.8 | 167 | 43 | 57 | 32 | 178 | 161.7 |
| | 3 Center | 23 | 1.60 | 63 | 24.6 | 147 | 52 | 30 | 14 | 123 | 151.5 |
| | 4 Wing | 31 | 1.77 | 96 | 30.6 | 124 | 84 | 20 | 15 | 213 | 154.1 |
| | 5 Wing | 27 | 1.70 | 74 | 25.6 | 139 | 96 | 49 | 19 | 150 | 153.7 |
| | 6 Wing | 18 | 1.67 | 69 | 24.7 | 186 | 123 | 48 | 34 | 213 | 156.3 |
| | 7 Wing | 21 | 1.65 | 74 | 27.2 | 148 | 66 | 55 | 19 | 70 | 155.3 |
| | 8 Wing | 23 | 1.68 | 63 | 22.3 | 161 | 64 | 52 | 18 | 91 | 160.3 |
| | 9 Wing | 35 | 1.79 | 79 | 24.7 | 154 | 74 | 31 | 52 | 157 | 145.1 |
| Mean | | | | | | 150.6 | 70.2 | 39.4 | 24.3 | 143.6 | 154.8 |
| SD | | | | | | 28.3 | 16.2 | 12.6 | 52.2 | 4.9 |

| Female players | Athlete | Age (yrs) | Height (m) | Body mass (kg) | BMI (kg/m\textsuperscript{2}) | Total PL (a.u.) | HIE (n) | Acc (n) | Dec (n) | CoDs (n) | Mean HR (bpm) |
|----------------|---------|-----------|------------|----------------|----------------|----------------|---------|---------|---------|----------|---------------|
| 1 Center | 15 | 1.52 | 48 | 20.8 | 75 | 33 | 35 | 15 | 51 | 153.4 |
| 2 Center | 20 | 1.55 | 50 | 20.8 | 118 | 39 | 28 | 14 | 114 | 148.1 |
| 3 Wing | 33 | 1.63 | 61 | 23.0 | 157 | 61 | 58 | 20 | 80 | 159.5 |
| 4 Wing | 19 | 1.56 | 54 | 22.2 | 146 | 86 | 78 | 10 | 141 | 160.6 |
| 5 Wing | 17 | 1.65 | 65 | 23.9 | 137 | 49 | 36 | 8 | 136 | 144.7 |
| Mean | | | | | | 126.6 | 53.6 | 47.0 | 13.4 | 104.4 | 153.3 |
| SD | | | | | | 32.2 | 21.0 | 20.7 | 4.7 | 38.3 | 6.9 |

Notes: BMI: body mass index; PL: PlayLoad\textsuperscript{TM}; HIE: high intensity events; Acc: acceleration; Dec: deceleration; CoDs: changes of direction; HR: heart rate.
individual differences in the mean PlayerLoad\textsuperscript{TM} in each sequence were found between the male and female players (p < 0.05).

3. PlayerLoad\textsuperscript{TM} during first and second halves and whole game in both male and female games (by position)

Figure-2 shows PlayerLoad\textsuperscript{TM} in every 10-sequence interval for each position (Center and Wings). As mentioned above, the individual differences in PlayerLoad\textsuperscript{TM} values by position was larger in male players than in female players. In addition, although not remarkable, there were PlayerLoad\textsuperscript{TM} differences between the Center and Wings positions. For the female players, PlayerLoad\textsuperscript{TM} values were relatively high in the Wings position.
4. Comparison between the peak PlayerLoad™ during a 10-sequence interval in a game and the following 10-sequence interval (after the peak), as average PlayerLoad™ in a 10-sequence interval

In male players, an approximately 50% decline in the mean value of PlayerLoad™ was observed from peak to post. The same tendency was observed in the female players, although the amount of decline was not that high (Figure-3).

5. HR responses expressed as %HRmax

Figure-4 shows the mean HR in each sequence during the first and second halves and whole game in both male and female players. The mean %HRmax during the first and second halves and whole game was 80.1 ± 1.2, 81.2 ± 2.8, and 80.6 ± 1.6 %HRmax, respectively, whereas that for the female players was 76.7 ± 4.9, 77.5 ± 6.4, and 77.1 ± 5.5 %HRmax, respectively, which showed no significant difference between male and female players. Figure-5 shows the degree of %HRmax observed during playing time. In male players, 80%-90% HRmax was observed in approximately 60% of a game, whereas that of female players was 30%. Furthermore, in female players, 70%-80% HRmax was observed in approximately 50% of a game, whereas that of male players was 30%. Differences were observed between male and female players in the %HRmax during playing time.

Discussion

The current research is the first to investigate goalball players, which focused on the physical load of the players during the game with the use of IMU.

In goal-type game analysis research for improving competitiveness, exercise intensity was generally calculated from the moving velocity during the game. However, research for soccer players shows frequent maximal accelerations from low velocities during match play, suggesting a substantial underestimation of the amount of high-intensity actions during a match. This may hold true for goalball, which has a short acceleration and deceleration and continuous movements of standing up and diving. The goalball players do not necessarily require long-distant movements or high-speed velocity. Therefore, the indicator PlayerLoad™ using IMU,
which is based on a technology different from moving distance and velocity, is thought to be suitable for calculating unique movements in goalball. Furthermore, in recent years, it has been a major tactic to attack as soon as possible, before the opponents have formed a defense system; thus, the frequency of throwing to attack and diving as defense is increasing. Under such situations, players’ physical abilities are important factors for winning the game. Therefore, research on calculating physical load during games can be regarded as extremely important. It is also important to study the reliability and validity of PlayerLoad™ in sports in developed countries.

As to HR responses, since the age of the current participants varied, the calculated value that converged from HRmax of their age was examined. The result showed no difference in tendency between sexes and between positions. For 80%-90% HRmax in a playing time, male players showed an 80%-90% HRmax in 60% of the game, whereas that for female players was 30%. Moreover, 70%-80% HRmax was observed in 50% and 30% of the playing time in female and male players, respectively.

Gawlik et al. reported the results of anthropometric measurements of 32 Polish goalball players, which were not remarkably different from weight and BMI of Japanese players in the current study. In addition, the results of HIE, Acc, Dec, and CoDs measured by using IMU in the current study were comparable to those of Uematsu (2018), who examined handball players. Furthermore, Fernandez (2009) showed that the exercise intensity in tennis players showed an average rate of 140-160 bpm and HRmax of 70%-80%, which were similar to the results of the current study. Therefore, goalball can be considered comparable with tennis and handball in terms of exercise intensity.

In the current study, taking into consideration the abovementioned goalball characteristics, we attempted to examine players’ physical load during the games using PlayerLoad™ as an indicator. As a result, there were no specific differences between sex and time progress. However, Wing players had a relatively high PlayerLoad™ than Center players. The possible reason for this is that the Wing players threw more and covered longer distances than Center players. In addition, in male players, post value decreased by approximately 50% from the peak value, whereas female players showed a decline that was not as high compared to that of male players. This data is important to guide instructors on how to lessen the difference during training (see Figure-3).

The current study indicates the importance of understanding scientific knowledge gained from actual games when considering goalball player characteristics, especially when planning training to lessen the difference between peak and post PlayerLoad™. In addition, to make the proportion larger, 80%-90% HRmax for male players and 70%-80% HRmax for female players within one
game can lead to improvement in competitiveness. Although the current study was the first to adopt a new method to determine the activity profiles of Japanese national goalball players, further studies comparing between sexes or positions and examining the training with a larger number of participants and games are warranted for planning a training method based on scientific evidence.

Conclusion

Our results provide scientific evidence in constructing useful measurement tools when planning trainings for goalball players to improve their competitiveness.

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