Relationships among postural stability, physical fitness, and shooting accuracy in Olympic female goalball players

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This study aims to examine the relationship between postural performance, physical fitness level, and shooting performance in Olympic female goalball players. Eight Olympic-level goalball players (age: 20.63 ± 4.37 years) were recruited from the Turkish National Women’s Goalball Team. Postural stability, physical fitness, and shooting performance of the players were measured. The postural stability was determined using body sway measurements during parallel and single-leg stances on a force plate. The physical fitness level of the players is evaluated by curl-up, isometric push-up, trunk lift, and grip strength (dominant hand) tests. A goalball-specific shooting accuracy test was used for shooting performance. Independent sample t-test and Pearson correlation were used for statistical processing. No statistical difference was observed in body sway parameters between open eyes and closed eyes conditions except for the anteroposterior sway area. Some of the body sway parameters performed under different stances positively correlated with all physical fitness tests (P<0.05). There was a positive correlation between the shooting accuracy and trunk lift score (r=0.787). Right leg sway area anterior-posterior and ellipse area negatively correlated with shooting accuracy (r= -0.629 and r= -0.692 respectively). It is necessary to attach importance to the improvement of the physical fitness level specific to core strength to maintain postural stability for visually impaired athletes. In our study, some factors affecting shooting accuracy were identified, but it is necessary not to restrict a complex structure such as shooting accuracy within certain concepts.

Keywords: Goalball, Postural sway, Strength, Throwing accuracy, Visual impairments

INTRODUCTION

There are some difficulties in the participation of disabled individuals in sports, but these difficulties are tried to be overcome owing to specially designed sports branches (Balcı et al., 2021; Makaracı et al., 2021). Regarding the participation of disabled individuals in sports, team sports come to the fore since they have a competitive nature in addition to factors such as the fulfillment of basic human needs, cooperation and communication (Wilson and Clayton, 2010). Team sports such as goalball, futsal, and football are sports branches which allow the participation of visually impaired (VI) individuals and for which tournaments are held at national and international levels (Kimyon and İnce, 2020). The popularity of goalball, which was included in the Paralympic Games in 1976 and in which VI athletes of all ages can participate, has been increasing every year (Molik et al., 2015; Monezi et al., 2019). Athletes classified into three categories such as B1, B2, and B3 according to their visual impairment can participate in competitions (Ravensbergen et al., 2016). Goalball is known to support the development of VI individuals in many aspects, such as physical, psychological, and cognitive characteristics (Petrigina et al., 2020). Considering that young VI individuals experience neuro-psychological and perceptual development, cardiovascular/muscular endurance, and postural problems compared to their peers with normal vision, the improving and rehabilitating effect of goalball on the physical level further comes to the fore (Skaggs and Hopfer, 1996).

Goalball is played on a modified volleyball court (18×9 m rectangular) with the participation of two teams, each including three players (Link and Weber, 2018). A rubber ball with a metal bell

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inside is used in the competition (Molik et al., 2015). The main purpose of the game is to try to score a goal by throwing the ball into the opponents’ goal with a height of 1.3 m and a width of 9 m, from the determined area of the team that has the ball (Goulart-Siqueira et al., 2018; Link and Weber, 2018). Thus, the team that scores more goals wins. The number of studies examining the shooting technique and shooting performance of goalball players is very limited. However, in a specially designed sports branch such as goalball, it is not possible to explain the shooting performance with a single variable. Goalball players use different shooting techniques, such as spinning, bouncing, and rolling, in addition to shooting velocity, for a more effective shooting performance (Monezi et al., 2019). Considering that three players try to defend the ball at the same time, it is vitally important to determine the mechanisms that affect the shots taken. Furthermore, it is not rational to evaluate goalball performance in terms of only attack and score-based actions. Players also try to defend their goals with their bodies by making inferences about the velocity and direction of the ball because of the sound of the bell inside. The effect of anthropometric and physical properties in defensive actions has been highlighted in previous studies (Molik et al., 2015). In this respect, goalball players need to have a good level of fitness to maintain defensive and offensive actions at an optimum performance.

Vision plays a crucial role in the planning and demonstration of motor skills, positioning, and the detection of people and objects (Hammami et al., 2014). Maintaining body balance and providing postural control are associated with vision (Van Emmerik et al., 2010). Factors such as following the ball, positioning and maintaining body stability during shooting in goalball, which involves VI athletes, can increase the relationship between proper balance and goalball-specific performance (Bednarczuk et al., 2017). Regardless of the competition level or sport, physical performance should be evaluated for the monitoring of factors such as the health status of athletes and the preparation for the competition. Despite the presence of some physical evaluation tests prepared for disabled athletes, there is no specific test for goalball players. Accordingly, in their review on physical fitness evaluation in goalball players, Petrigna et al. (2020) reported that the Brockport Physical Fitness Test (BPFT) battery was a test that could be used in goalball players. In this sense, the musculoskeletal function of the goalball athlete can be evaluated with the BPFT test. Core strength, which is a strong reflection of musculoskeletal function, is of vital importance for body balance (Aksen-Cengizhan et al., 2018). Therefore, the relationship between the functions of the core area and postural sway comes to the fore as a noteworthy issue.

To the best of our knowledge, no studies have been conducted on Olympic goalball team players using a specific shooting test. This study aims to examine the relationship between postural performance, physical fitness level, and shooting performance in Olympic female goalball players. It is thought that the findings obtained as a result of the study will practically contribute to the practices in the field.

**MATERIALS AND METHODS**

**Study design**

A descriptive study design was used to evaluate the relationships among postural stability, physical fitness features, and shooting accuracy of Olympic female goalball players. The Turkish National Women’s Goalball Team, which won the gold medal at the Tokyo 2020 Paralympic Games was in a camping period prior to the 2022 IBSA Goalball World Championships. The study was conducted in the training facilities of the athletes. The study measurements included 2 days of evaluation separated by a minimum of 24 hours of rest. On the first day, participants were evaluated for anthropometric, body sway, physical fitness, and dominant hand (DH) grip strength measurements. On the second day, a goalball-specific shooting accuracy test prepared by the study authors was performed following a self-controlled shot practice for test adaptation. Both measurements (days 1 and 2) were taken at the same time of day (mid-day). As a familiarization process is not required with athletes of this level, a separate session for familiarization before the measurement day was not performed. The athletes did not perform any exercise during the study period. To reduce the attempt of uncontrolled data, all athletes were instructed to maintain their usual way of life and routine diet program prepared by the team staff during the study.

**Participants**

Eight Olympic-level goalball players (age: 20.63±4.37 years) were recruited from the Turkish National Women’s Goalball Team with experience in the Paralympic Games and World Cup. The players trained ≥6 times/wk for ≥120 min, had an average experience in the sport of 9.01 ± 4.11 years, and competed regularly in the Turkish Goalball championship. Seven players were classified as B2 (visual acuity ranging from 1.50 to 2.60 and/or a visual field constricted to a diameter of fewer than 10°) and one player as B1 (totally or almost totally blind). The players were informed about the study conditions and provided written informed consent. The study was accepted with the approval (Document No: 05-2022-...
101) of the Ethics Committee of Karamanoğulları Mehmetbey University.

The selection criteria of the athletes were as follows: being a member of the current National Women’s Goalball Team and volunteering to participate in this study. The elimination criteria included the following: having any kind of musculoskeletal injury in the past 6 months, having any neurological or cardiovascular diseases, and pain or discomfort reported during testing.

**Anthropometric measurements**

The athletes’ body mass (kg) was measured by the force plate (automatically before body sway measures), their height (m) was measured by a stadiometer (SECA-Mod.220, Seca GmbH & Co. KG., Hamburg, Germany) and body mass index was calculated afterward.

**Assessment of body sway**

A force plate (type 9260AA6; 60 × 50 × 5 cm; natural frequency = 400, Kistler, Winterthur, Switzerland) paired with Kistler’s Measurement, Analysis and Reporting software (MARS, v4.0.2.99, S2P Ltd., Ljubljana, Slovenia) was used to assess body sway by center of pressure fluctuations and relative parameters for each athlete.

All athletes completed postural sway tests in parallel, left, and right leg stances. The data was collected for open eyes (OE) and closed eyes (CE) conditions. A 10-min general warm-up session was performed by the athletes prior to the test. Athletes performed body sway measures according to the protocol applied by Makaracı et al. (2021). During the recordings, athletes were to stand as still as possible and avoid any kind of body movements and talking. The walking shoes were preferred throughout the measurements. The athletes were tested twice consecutively in each stance, and the average of the two test administrations was used to calculate the test results.

Shorter time intervals during the body sway measurements are associated with lower reliability (Kozinc et al., 2021). Therefore, 30-s intervals were chosen during the parallel stance measures (Trajković et al., 2021). A 10-sec duration was selected during left and right leg stance measures due to the difficulty of testing (Kozinc and Šarabon, 2021). Total, anteroposterior, and mediolateral directions sway path, velocity, and area obtained from the MARS are used as parameters of the body sway assessment.

**Physical fitness assessment**

The BPFT test was used to determine the musculoskeletal functioning and muscular strength/endurance of the goalball players. It is a valid test of the health-related physical fitness assessment, appropriate for VI athletes (Petrigina et al., 2020). Some selected parameters of the BPFT were used in the presented study. The test parameters used in the study are as follows: curl-up (modified), isometric push-up, trunk lift, and grip strength (DH).

Curl-up test was to perform many curl-ups as possible following a cadence of one every three seconds. The hands rest on the thighs for a complete repetition. The number of complete curl-ups performed was recorded. During the isometric push-up test, the athletes are required to hold a raised push-up position for as long as 40 sec. However, in the present study, the athletes were instructed to hold a raised push-up position of maximum duration because of the athletes’ level. The back strength of the athletes was tested by trunk lift. Athletes used the back muscles to lift the upper body up and to hold the position for at least 1-sec while lying face down. The best of three trials for the trunk lift test was recorded. A hand dynamometer (Baseline Smedley, Model 12-0286, White Plains, NY, USA) was used to measure the grip strength of the athletes. Athletes assumed a standing position with their elbows extended perpendicular to the floor. The dynamometer axis was visually aligned with the arm by the tester. The grip width was self-selected and it was kept constant for all measurements. The athletes were asked to hold the dynamometer with DH as tight as possible for 3 sec and free it afterward. Three trials were performed, and the average of the three trials was used.

**Shooting accuracy protocol**

It has been observed that there is no valid shooting accuracy test specific to goalball players in the literature. Accordingly, a test protocol was created to examine similar studies and investigate the shooting performance of Olympic-level athletes by obtaining the opinions of the national goalball team coach (Fig. 1).

In the test protocol created, the players took shots at the standard goalball goal, which was located in the throwing area and divided into a total of six equal sectors at 1.5-m intervals, from the center of their own defense areas. Among the most preferred shooting types in goalball, which the players are also used to, rolling and/or bouncing styles were preferred while shooting. The players were given the opportunity to choose the style they wanted during shooting accuracy protocol. The shots were taken as five shots for each sector (a total of 30 shots). The shots were taken respectively in sectors 1, 2, 3, 4, 5, and 6 at the opponents’ goal with no defense players. The players were given sufficient rest time between the following shots. To comply with the conditions...
of the official competition, it was emphasized that the players should shoot as fast and as accurately as possible. As a result, the shooting performance of the players was determined by recording the accurate shots. In all shots, the official goalball (WV brand, 1.25 kg) and a standard eye shade preferred in the Olympic games were used. During the test, the goalball game rules were valid, and shots that did not comply with the rules were considered invalid. The formula below was used to determine the athletes’ shooting accuracy.

\[
\text{Shooting accuracy} = \frac{\text{accurate shot number}}{\text{total shot number}} \times 100
\]

**Statistical analysis**

Data were analyzed using IBM SPSS Statistics ver. 24.0 (IBM Co., Armonk, NY, USA). The statistics of descriptive variables were reported using mean and standard deviation (SD). The normality of distribution was tested by the Kolmogorov–Smirnov test. Since the data were normally distributed, the Independent sample \(t\)-test was conducted to compare differences between the results of the body sway measurements with OE in compared with CE in parallel, left, and right leg stance positions. Effect sizes for \(t\)-test were calculated as Cohen’s \(d\) recommendations: where 0.2–0.49 is a small effect, 0.5–0.79 is a moderate effect, and ≥0.8 is a large effect (Bernards et al., 2017). Pearson correlation coefficient was used to establish relationships between body sway and physical fitness parameters and shooting accuracy. The magnitude of the correlation (\(r\)) between the test measures was assessed with the following thresholds: ≤0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and 0.9–1.0, almost perfect (Hopkins et al., 2009). For all analyses, the threshold for statistical significance was set at \(P < 0.05\).

**Table 1.** Demographic and physical fitness characteristics of the athletes (\(n = 8\))

| Variable                          | Mean ± SD   |
|----------------------------------|-------------|
| Age (yr)                         | 20.63 ± 4.37|
| Body height (m)                  | 1.65 ± 0.06 |
| Body weight (kg)                 | 61.25 ± 8.1 |
| Body mass index (kg/m\(^2\))     | 23.73 ± 2.78|
| Sports experience (yr)           | 9.01 ± 4.11 |
| Curl-up (n)                      | 80 ± 35.4   |
| Isometric push-up (sec)          | 333.75 ± 33.5|
| Trunk lift (cm)                  | 33.5 ± 5.45 |
| Grip strength (dominant hand) (kg)| 37.6 ± 5.53 |

SD, standard deviation.
RESULTS

The basic demographic and physical fitness characteristics of the athletes are presented in Table 1. Descriptive data for shooting performances of the athletes by each sector area is presented in Table 2. Table 2 showed that the highest shooting accuracy was in sector 5 while the lowest shooting accuracy was in sector 6. Differences between the results of the body sway measurements with OE compared to with CE in parallel, left and right leg stances

Table 2. Descriptive data for shooting performances of the athletes by each sector area

| Sector | No. of shots | Mean ± SD | Range |
|--------|--------------|-----------|-------|
| S1     | 5            | 1.88 ± 1.46 | 0–4   |
| S2     | 5            | 1.88 ± 0.45 | 1–2   |
| S3     | 5            | 2.0 ± 0.33  | 1–3   |
| S4     | 5            | 1.88 ± 0.83 | 1–3   |
| S5     | 5            | 2.5 ± 1.07  | 1–4   |
| S6     | 5            | 1.63 ± 0.92 | 0–3   |

SD, standard deviation.

Table 3. Differences between the results of the body sway measurements with open eyes (OE) in compared to with closed eyes (CE) in parallel, left, and right leg stances

| Variable | Parallel stance | Left leg stance | Right leg stance |
|----------|----------------|----------------|-----------------|
|         | Mean ± SD | P-value | ES | Mean ± SD | P-value | ES | Mean ± SD | P-value | ES |
| SPT (mm) |          |         |    |          |         |    |          |         |    |
| OE      | 450.5 ± 101.25 | 0.855 | 0.09 | 676.03 ± 115.83 | 0.566 | 0.29 | 689.46 ± 158.6 | 0.981 | 0.01 |
| CE      | 459.43 ± 89.72 |        |    | 720.89 ± 182.08 |        |    | 691.31 ± 140.05 |        |    |
| SPAP (mm) |          |         |    |          |         |    |          |         |    |
| OE      | 249.38 ± 69.35 | 0.574 | 0.28 | 461.46 ± 97.09 | 0.913 | 0.05 | 461.35 ± 81.85 | 0.744 | 0.16 |
| CE      | 271.89 ± 86.29 |        |    | 466.7 ± 90.92 |        |    | 479.8 ± 133.57 |        |    |
| SPML (mm) |          |         |    |          |         |    |          |         |    |
| OE      | 312.88 ± 73.11 | 0.859 | 0.09 | 395.31 ± 69.56 | 0.360 | 0.47 | 397.41 ± 80.54 | 0.630 | 0.24 |
| CE      | 318.49 ± 48.35 |        |    | 454.6 ± 163.17 |        |    | 422.45 ± 118.99 |        |    |
| SVT (mm/sec) |          |         |    |          |         |    |          |         |    |
| OE      | 15.88 ± 4.93 | 0.782 | 0.14 | 67.61 ± 11.59 | 0.566 | 0.29 | 68.95 ± 15.86 | 0.981 | 0.01 |
| CE      | 16.61 ± 5.38 |        |    | 72.09 ± 18.21 |        |    | 69.14 ± 14.01 |        |    |
| SVAP (mm/sec) |          |         |    |          |         |    |          |         |    |
| OE      | 8.58 ± 2.69 | 0.467 | 0.37 | 46.15 ± 9.71 | 0.913 | 0.05 | 46.14 ± 8.19 | 0.745 | 0.16 |
| CE      | 9.94 ± 4.4 |        |    | 46.68 ± 9.09 |        |    | 47.99 ± 13.36 |        |    |
| SVML (mm/sec) |          |         |    |          |         |    |          |         |    |
| OE      | 11.25 ± 3.75 | 0.880 | 0.07 | 39.53 ± 6.95 | 0.360 | 0.47 | 39.74 ± 8.05 | 0.629 | 0.24 |
| CE      | 11.53 ± 3.99 |        |    | 45.46 ± 16.32 |        |    | 42.25 ± 11.9 |        |    |
| SAT (mm²) |          |         |    |          |         |    |          |         |    |
| OE      | 986.23 ± 456.76 | 0.920 | 0.05 | 2,796 ± 873.67 | 0.435 | 0.40 | 3,201 ± 1,131.81 | 0.935 | 0.04 |
| CE      | 1,009.99 ± 468.9 |      |    | 3,258.25 ± 1,371.19 |      |    | 3,247.5 ± 1,123 |      |    |
| SAAP(mm*sec) |          |         |    |          |         |    |          |         |    |
| OE      | 65.4 ± 21 | 0.038* | 1.15 | 72.65 ± 11.45 | 0.092 | 0.90 | 78.31 ± 8.55 | 0.706 | 0.19 |
| CE      | 90.94 ± 23.07 |      |    | 86 ± 17.43 |        |    | 81.54 ± 21.97 |        |    |
| SAML (mm/sec) |          |         |    |          |         |    |          |         |    |
| OE      | 111.33 ± 14.21 | 0.207 | 0.69 | 76.62 ± 18.61 | 0.248 | 0.60 | 80.48 ± 25.09 | 0.158 | 0.74 |
| CE      | 153.63 ± 85.41 |      |    | 87.65 ± 17.99 |        |    | 90.63 ± 23.56 |        |    |
| EA %100 (mm²) |          |         |    |          |         |    |          |         |    |
| OE      | 59.99 ± 19.68 | 0.646 | 0.23 | 272.64 ± 106.17 | 0.180 | 0.70 | 317.48 ± 110.81 | 0.434 | 0.40 |
| CE      | 67.84 ± 43 |      |    | 354.41 ± 127.54 |      |    | 358.21 ± 90.57 |      |    |

Where ≤ 0.2 = small, ≤ 0.5 = medium, and ≤ 0.8 = large.
SD, standard deviation; ES, Cohen d effect size; SPT, sway path total; SPAP, sway path anterior-posterior; SPML, sway path medial-lateral; SVT, sway velocity total; SVAP, sway velocity anterior-posterior; SVML, sway velocity medial-lateral; SAT, sway area total; SAAP, sway area anterior-posterior; SAML, sway area medial-lateral; EA %100, area of 100% ellipse.
*P<0.05.
were normally distributed and presented in Table 3. For all body sway parameters higher mean values were noted in CE condition compared to OE condition. No statistical difference was observed in body sway parameters between OE and CE conditions ($P > 0.05$).

### Table 4. Correlation coefficients between body sway and physical fitness parameters

| Parameter | Curl-up | Isometric push-up | Trunk lift | GS (DH) |
|-----------|---------|--------------------|------------|---------|
|           | OE      | CE                 | OE         | CE      | OE     | CE     |
| SPT (mm)  |         |                    |            |         |        |        |
| PS        | 0.312   | -0.207             | -0.571     | -0.469  | 0.623* | 0.616  | 0.357  | 0.120  |
| LLS       | -0.016  | -0.078             | -0.665*    | -0.630* | 0.321  | 0.040  | 0.054  | -0.729*|
| RLS       | 0.285   | 0.040              | -0.189     | -0.247  | -0.034 | -0.609 | 0.558  | -0.014 |
| SPAP (mm) |         |                    |            |         |        |        |
| PS        | 0.443   | 0.211              | -0.712*    | -0.532  | 0.545  | 0.560  | 0.416  | 0.227  |
| LLS       | 0.062   | -0.104             | -0.533     | -0.835**| 0.469  | 0.596  | -0.013 | 0.547  |
| RLS       | 0.423   | -0.292             | -0.119     | -0.338  | 0.111  | -0.786*| 0.623  | 0.078  |
| SPML (mm) |         |                    |            |         |        |
| PS        | -0.158  | -0.476             | -0.390     | -0.224  | 0.536  | 0.448  | 0.099  | 0.079  |
| LLS       | -0.194  | -0.056             | -0.777*    | -0.400  | 0.149  | -0.248 | 0.108  | -0.673*|
| RLS       | -0.056  | 0.208              | -0.189     | -0.246  | -0.034 | -0.609 | 0.422  | -0.023 |
| SVT (mm/sec) |       |                    |            |         |        |
| PS        | -0.199  | -0.412             | -0.803*    | -0.673* | 0.473  | 0.513  | -0.069 | -0.112 |
| LLS       | -0.016  | -0.078             | -0.665*    | -0.630* | 0.321  | 0.040  | 0.054  | -0.729*|
| RLS       | 0.266   | 0.040              | -0.189     | -0.246  | -0.034 | -0.609 | 0.558  | -0.014 |
| SVAP (mm/sec) |      |                    |            |         |        |
| PS        | -0.019  | 0.029              | -0.868**   | -0.654* | 0.461  | 0.532  | 0.050  | 0.085  |
| LLS       | 0.062   | -0.104             | -0.533     | -0.835**| 0.469  | 0.596  | -0.013 | 0.547  |
| RLS       | 0.423   | -0.292             | -0.119     | -0.338  | 0.111  | -0.786*| 0.623  | 0.078  |
| SVML (mm/sec) |       |                    |            |         |        |
| PS        | -0.466  | -0.649*            | -0.691*    | -0.589  | 0.574  | 0.407  | -0.240 | -0.194 |
| LLS       | -0.194  | -0.056             | -0.777*    | -0.401  | 0.149  | -0.248 | 0.109  | -0.672*|
| RLS       | -0.056  | 0.208              | -0.189     | -0.246  | -0.034 | -0.609 | 0.422  | -0.023 |
| SAT (mm^2) |       |                    |            |         |        |
| PS        | 0.454   | -0.137             | -0.623*    | -0.448  | 0.150  | 0.430  | -0.663*| 0.020  |
| LLS       | -0.246  | -0.020             | -0.465     | -0.440  | 0.248  | 0.052  | -0.434 | 0.808* |
| RLS       | 0.217   | 0.605              | -0.162     | 0.024   | -0.355 | -0.294 | 0.311  | -0.246 |
| SAAP (mm*sec) |      |                    |            |         |        |
| PS        | 0.561   | 0.133              | -0.458     | 0.009   | -0.017 | -0.085 | 0.421  | 0.501  |
| LLS       | -0.437  | -0.488             | -0.081     | -0.108  | 0.269  | -0.147 | -0.656*| 0.452  |
| RLS       | 0.253   | 0.381              | 0.287      | 0.544   | -0.395 | 0.520  | 0.229  | -0.647*|
| SAML (mm*sec) |     |                    |            |         |        |
| PS        | 0.266   | -0.183             | -0.246     | -0.519  | -0.085 | 0.393  | -0.194 | -0.395 |
| LLS       | -0.559  | 0.025              | -0.187     | -0.118  | 0.212  | 0.045  | -0.579 | -0.697*|
| RLS       | -0.010  | 0.892**            | 0.074      | 0.219   | -0.535 | 0.187  | -0.298 | -0.327 |
| EA %100 (mm^2) |    |                    |            |         |        |
| PS        | 0.258   | -0.090             | -0.712*    | -0.539  | -0.191 | 0.385  | 0.412  | -0.104 |
| LLS       | -0.444  | -0.148             | -0.422     | -0.201  | 0.310  | 0.030  | -0.546 | -0.701*|
| RLS       | 0.019   | 0.404              | 0.158      | 0.378   | -0.595 | -0.439 | -0.060 | 0.285  |

GS, grip strength; DH, dominant hand; OE, open eyes; CE, closed eyes; SPT, sway path total; SPAP, sway path anterior-posterior; SPML, sway path medial-lateral; SVT, sway velocity total; SVAP, sway velocity anterior-posterior; SVML, sway velocity medial-lateral; SAT, sway area total; SAAP, sway area anterior-posterior; SAML, sway area medial-lateral; EA %100, area of 100% ellipse; SP, stance position; PS, parallel stance; LLS, left leg stance; RLS, right leg stance.

*P<0.05. **P<0.01.
except for sway area anterior-posterior (SAAP) during parallel stance ($P = 0.036$). Table 4 shows the correlation coefficients between body sway and physical fitness parameters of the athletes. According to the correlation results given in Table 4, some of the body sway parameters performed under different stance conditions were found to be related to physical fitness parameters ($P < 0.05$). Curl-up score was significantly correlated with sway velocity medial-lateral (SVML) during parallel stance and SAML during right leg stance in CE condition ($r = -0.649$ and $r = 0.892$). The isometric push-up score was significantly correlated with sway path total (SPT) during left leg (OE, CE); SPAP during parallel (OE) and left leg (CE); SPML during left leg (OE); SVT during parallel (OE, CE) and left leg (CE); SPAP during parallel (OE, CE) and left leg (CE); SAT and ellipse area (EA) during parallel leg stance (OE) positions ($r = -0.623$ to $-0.868$). Trunk lift score was significantly correlated with SPT during parallel leg (OE); SPAP and SVAP during right leg stance (CE) positions ($r = 0.623$, $r = -0.786$, and $r = -0.786$ respectively). The grip strength score was significantly correlated with SPT, SPML, SVT, SVML, SAT, SAAP, SAML, and EA during left leg stance position and in CE conditions ($r = -0.673$ to $-0.808$). The grip strength score was also significantly correlated with SAT during parallel leg (OE), SAAP during left leg (OE), and SAAP during right leg stance (CE) positions ($r = -0.663$, $r = -0.656$, and $r = -0.647$ respectively).

Fig. 2 demonstrates the statistically significant correlation graphs between body sway and physical fitness parameters of the athletes. There was a positive and large level correlation between the shooting accuracy and trunk lift score (Fig. 2A) ($P < 0.05$, $r = 0.767$). SAAP (OE) and EA (OE) during right leg stance position had a negative and moderate level correlation with shooting accuracy (Fig. 2B) ($P < 0.05$, $r = -0.692$).

**DISCUSSION**

In sports with different game dynamics such as goalball, the analysis of the factors related to game performance outputs seems interesting. The ultimate aim in goalball is to score more goals by taking effective and successful shots at the opponents’ goal. It is not easy to analyze a concept, such as shooting accuracy, which has a complex structure and is likely to be affected by different internal/external factors. There are no specific shooting accuracy protocols for the goalball, and effect mechanisms are not completely clear. So, the number of studies is limited. This study aims to examine the relationship between postural performance, physical fitness level, and shooting performance in Olympic female goalball players. The study measurements on active goalball team players at the Olympic level have a unique structure, particularly in terms of evaluating the shooting accuracy performance using a specific protocol.

In goalball, ensuring postural stability is associated with the defense of the goal, following the ball, and maintaining the position in defensive actions and with the optimization of shooting biomechanics in offensive actions (Bednarczuk et al., 2017). The asymmetrical balance of the body is known to affect the postural mechanism because both legs have different motor functions. In a postural action, one leg tries to apply motor skills, while the other leg helps to support body mass (Paillard and Noé, 2020). In this context, it is known that the probable postural difference between the two legs may affect motor (i.e., power, agility) and sportive (i.e., sprint) performance (Bishop et al., 2018). In the present study,
the body sway performances of the players were examined in parallel, left, and right leg stance positions. According to the results analyzed on the axis of the body sway area and velocity, no statistical difference was observed between the left and right leg body sway measures (except for SAAP during parallel stance) \((P > 0.05)\) (Table 3). We think that this finding may be related to the physical characteristics and fitness level of the Olympic level athletes. Moreover, the fact that players have visual impairments is considered another factor that causes this relation. In addition to being the center of the body, core strength, which has a significant effect on musculoskeletal functions, is known to be correlated with body stability (Cobb et al., 2014). Yu and Lee (2012) reported that core region training improves postural control. According to the results obtained in our study, curl-up, isometric push-up, and trunk lift were found to be correlated with body sway parameters \((P < 0.05)\) (Table 4). Among these parameters, SVT and SVAP during parallel stance were revealed to have a large and negative correlation with isometric push-up performance \((r = -0.803\) and \(r = -0.868\), respectively). The correlation of the statically performed isometric push-up performance, which is a strong indicator of muscular endurance, with the sway measures performed in the parallel stance, shows that both legs are active and the core strength is important in terms of protecting the body posture. In our study, the participants’ performance in the isometric-push-up test was quite striking \((33.75 \pm 33.50\) sec) (Table 1). Hence, it can be said that the validity of this relationship, which has a large correlation value \((r = 0.7–0.9)\), increased. Isometric push-up performance was found to have a large level of negative correlation with SPAP and SVAP parameters, which refer to the path swayed in the anterior-posterior direction and sway velocity of the left leg \((r = -0.835\) for both parameters). Considering that almost all of the players have dominant right legs, the relationship between the postural sway parameters of the left leg, which is mostly used as the support leg, and the core strength is a noteworthy finding.

The hand, which has a complex structure due to containing a large number of bones and joints, is extremely important in terms of grasping objects of certain sizes, moving them in a controlled manner, and normal biokinetic function of the hand area (Bonitch-Góngora et al., 2012). The grip strength is considered a performance parameter in most sports (Cronin et al., 2017; Watanabe et al., 2005) and it is one of the sections of the BPFT, is also used extensively as an indicator of whole-body strength. As a result, a probable decrease in body strength is shown as the precursor of postural problems (Alonso et al., 2018). According to the study results, all body sway parameters, except for SPAP and SVAP, were found to be correlated with the grip strength (DH) \((P < 0.05; r = -0.647\) to \(-0.808)\). Almost all the existing correlations were detected in the measurements performed in the case of left leg stance. This finding indicates an asymmetric relationship between grip strength (right hand) and body sway measures during left leg stance positions. The findings obtained in the grip strength, which is a part of the BPFT (Petrigna et al., 2020), a valid test in the evaluation of the physical fitness levels of goalball players, are thought to be an issue that should be emphasized in the study in which the Olympic-level participant group took part.

Due to the nature of goalball, defensive and offensive actions should be performed together (Alves et al., 2018). In this sense, to improve goalball-specific sportive performance, physical capacity should not be ignored. As in other sports involving shooting patterns, it can be said that there are many factors affecting shooting accuracy in goalball, where shots are taken in different techniques and mechanics. Considering that postural problems come to the fore in VI individuals (Kurz et al., 2021), it can be inferred that this situation may affect the shooting performance of goalball players. According to the results of the planned study-specific shooting accuracy test, the average of accurate shots on a sector basis seem similar (Table 2). According to the correlation findings, a positive correlation was identified between trunk lift performance and shooting accuracy \((P < 0.05, r = -0.767)\) (Fig. 1A). A negative correlation was observed between SAAP (OE) and EA (OE) during right leg stance, and shooting accuracy \((P < 0.05, r = -0.629, r = -0.692)\) (Fig. 1B, C). There was no correlation between the other postural sway parameters, physical fitness tests and shooting accuracy \((P > 0.05)\). Kimyon and İnce (2020) reported in their study on goalball players that there was a positive correlation between DH grip strength and shooting performance (calculated from referees’ report). In our study in which a goalball-specific shooting protocol was used, this correlation was not statistically significant \((P > 0.05)\). It is seen that the findings of the present study are parallel with the aforementioned correlation between postural control and physical capacity. It can be stated that body sway parameters, which are characterized by trunk lift, a marker of core strength, and right leg-related sway area, are the factors that should be given priority when evaluating shooting accuracy in goalball players. Considering the level of the participant group in the study, it can be said that the practical use of the results of the shooting accuracy protocol consisted of 30-shots performed in different shooting sectors may be quite common. The lack of studies examining goalball-specific shooting performance according to different variables limits the discussion of the study findings on the axis of the
In conclusion, it was elucidated that there was no performance difference between the left and right legs in the body sway measurements of Olympic-level female goalball players. Body sway measures in different stance positions were found to be associated with the physical fitness level. Furthermore, it can be interpreted that goalball-specific shooting performance and trunk lift and body sway parameters (SAAP and EA) characterized by the right leg may be correlated. Within the dynamics of goalball, it is necessary to attach importance to the improvement of the physical fitness level and activities specific to core strength to maintain postural stability. According to the study findings, some factors affecting shooting accuracy were identified, but it is necessary not to restrict a complex structure such as shooting accuracy within certain concepts.

Among the study limitations, the sample size should be considered as the main factor although it is hard to collect data from Paralympic level athletes. However, the fact that the participant group consisted of athletes at the highest level of the relevant branch may decrease the effect of this limitation on the results. The lack of validity of the shooting accuracy protocol used in the study prevents the generalization of the findings related to shooting accuracy. Moreover, the absence of the male participant group in the study is another limitation. Conducting future studies with the participation of male athletes and with a large number of samples may contribute to the literature.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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