Journal of Human Kinetics volume 82/2022, 275-282 DOI: 10.2478/hukin-2022-0081
Section IV – Behavioural Sciences in Sport & Sport for the Disabled

sciendo

Hand Grip Strength vs. Locomotor Efficiency in Sitting Volleyball Players

by
Wojciech Wiliński[1], Artur Struzik[2], Andrzej Rokita[3], Milada Krejci[4], Marta Wieczorek[1]

The objective of this paper was to determine the relationship between hand grip strength and movement time (locomotor efficiency in a seated position using the upper and lower extremities) in sitting volleyball players. In addition, a comparison was made between the velocity curves for forward and backward locomotion. Nine male members of the sitting volleyball team participated in the study. Hydraulic and spring manual dynamometers were used to measure hand grip strength. Movement times were registered for distances of 1, 2, 3, 4, 5, 6 and 10-m with the use of the Smart Speed System photocells. Significant relationships between hand grip strength of the left (r_s=-0.78) and right (r_s=-0.73) hands and the forward movement time over a distance of 1-m were found. Hand grip strength had no significant relationship with either forward movement times at other distances or backward movement times. Results suggest that hand strength is linked to locomotor efficiency of sitting volleyball players. High hand grip strength makes the start easier by pushing away from the ground with the upper limbs.

Key words: *disabled athletes, locomotor efficiency, motor abilities, sitting volleyball.*

Introduction

Sitting volleyball is a type of volleyball designed for people with lower extremity dysfunction, cerebral palsy, motor organ disorders (the "Les Autres" group), minimal disability and those who have undergone amputations of the lower limbs. Movement technique in sitting volleyball is unique. It consists of moving ("sliding") on buttocks on the floor using the lower and upper extremities. The velocity and correctness of movement technique are preconditions in sitting volleyball performance. The correct movement technique results from involvement of the upper limbs not only in contact with the ball, but also in the correct positioning of the player on the court (Abadżijew, 2014).

The times of locomotion in a seated position at 3 and 5-m distances showed negative relationships with height in the position to the block and height in the position to spike (measured in a seated position), and the arm reach in elite sitting volleyball players (Marszałek et al., 2015). This result may also indicate a significant role of upper limb dimensions during dynamic locomotion in sitting volleyball. Molik et al. (2008) reported that shorter time during 5 m locomotion in a seated position was associated with greater distance of passing the ball with both hands in front of the chest in sitting volleyball players. Additionally, Jadczak et al. (2010) found that shorter times obtained in endurance and speed tests were related with performance in sitting volleyball players.

[1] - *Department of Methodology of School Physical Culture, Wroclaw University of Health and Sport Sciences, Wrocław, Poland.*
[2] - *Department of Biomechanics, Wroclaw University of Health and Sport Sciences, Wrocław, Poland.*
[3] - *Department of Team Sport Games, Wroclaw University of Health and Sport Sciences, Wrocław, Poland.*
[4] - *College of Physical Education and Sport PALESTRA, Prague, Czech Republic.*

Authors submitted their contribution to the article to the editorial board.
Accepted for printing in the Journal of Human Kinetics vol. 82/2022 in April 2022.

However, there is no certainty as to the relationship between hand grip strength and locomotor efficiency of sitting volleyball players. Hand grip strength increased over a period of ten months in sitting volleyball players with a significant degree of disability and did not change in players with a moderate degree of disability and in healthy players (Jadczak et al., 2009). In addition, hand grip strength showed no relationship with sitting volleyball performance (Jadczak et al., 2010). Koley and Bijwe (2014) reported positive relationships of grip strength in the dominant hand with anthropometric variables (body height, body mass, BMI, hand length) and negative relationships with a body fat ratio and Illinois Agility Test performance in volleyball players. However, for women judoists, hand grip strength was shown to be a competition predictor (Sánchez et al., 2011). Hand grip strength is also a predictor of disability (25 years later) in initially healthy men aged 45-68 years (Rantanen et al., 1999) and its measurement is one of the well-known tools (Cardiovascular Health Study Scale) used to diagnose frailty syndrome (Uchmanowicz et al., 2014). Hand grip strength is not only an important predictive factor of health issues, but also a precondition for complex activities in everyday life. Its variability is mainly determined by environmental factors, which indicates that there are great opportunities for its development by local strength training (Angst et al., 2010; Leong et al., 2015; Tiainen et al., 2004).

Performance in sitting volleyball, due to the technique of locomotion, depends strongly on the movements of upper limbs (Abadżijew, 2014). Previous reports (Marszałek et al., 2015; Molik et al., 2008) analysed the locomotion of sitting volleyball players mainly at distances of 3 and 5-m. However, when looking at the dimensions of the court (two halves of 5x6m), it seems reasonable to use a distance of at least 6 m to assess locomotor efficiency in a seated position. The distance that the player must cover varies in each action of the game and depends on the flight of the ball and the situation on the court. Therefore, the measurements of locomotion times for various distances shorter than 6 m (1m, 2m, 3m, 4m, or/and 5m) are also reasonable. Additionally, sitting locomotion is still a relatively little explored area. Finding a factor that would be responsible for locomotor efficiency in a seated position would help optimize the training process. The measurement of hand grip strength is relatively simple and possible under any conditions.

Therefore, the objective of this paper was to determine the relationship between hand grip strength and movement time (locomotor efficiency in a seated position with the use of the upper and lower extremities) in sitting volleyball players. In addition, a comparison was made between the velocity curves for forward and backward locomotion in a seated position. The following research questions were formulated:

1. Is there a relationship between hand grip strength and movement times for distances of 0-1, 0-2, 0-3, 0-4, 0-5, 0-6 and 0-10m in sitting volleyball players?
2. What is the slope of the velocity curve of forward and backward locomotion at distances of 0-1, 1-2, 2-3, 3-4, 4-5, 5-6 and 6-10m in sitting volleyball players?
3. Is forward and backward locomotion velocity similar at distances of 0-1, 1-2, 2-3, 3-4, 4-5, 5-6 and 6-10m in sitting volleyball players?

Methods

Participants

Nine men from the sitting volleyball team "Start" Wrocław participated in the study. The tests were carried out before training, but after an individual warm-up. Before the tests began, participants signed an informed consent form. Participants filled in the form in which they provided information on their disability, training experience and sports level. Regarding the time when the disability appeared, two participants had congenital disabilities, and seven participants had acquired disabilities. One of sitting volleyball players had a mild disability, seven had moderate disabilities, and one suffered from a severe disability. Among the investigated players, two belonged to the group with minimal disability. Anthropometric and training characteristics of sitting volleyball players are presented in Table 1.

Testing Procedures

A SAEHAN hydraulic manual dynamometer manufactured by Jamar was used to measure grip strength in the left and right hands. Participants performed the test in a seated position with arms placed along the torso, the elbow joint bent at a 90^{o} angle and the forearm and the wrist in a neutral position according to the standard measurement procedure (Reddon et al., 1985). Additionally, to measure the grip strength of the left and right hands, a manual T.K.K. 5001 Grip spring dynamometer was used. The tests were performed in the standing position with the upper limbs straightened and placed along the torso. In both hand grip strength measurements, participants gripped the dynamometer handle twice with the left and right hands. For further analysis, the highest values of hand grip strength for each participant were used (for both upper extremities with two measuring conditions).

Participants performed two trials of the forward and backward movement in a seated position using the upper and lower extremities over a distance of 10-m in a straight line. For further analysis, trials taking less time to complete the 10-m distance (forward and backward) for each participant were taken into consideration. The time at individual sections was recorded by means of a Fusion Smart Speed System (Fusion Sport, Coopers Plains, QLD, Australia). The system consists of gates made of photocells containing heads emitting infrared light and mirrors reflecting the light. The test was carried out using eight gates. A distance of 2-m was maintained between the photocells and mirrors. From the starting line onwards, the next gates were placed to record the time when IR beams were broken. The gate placed 10 m away from the starting line marked the finish line. The start occurred voluntarily from a seated position. The upper extremities of participants were set immediately in front of the starting line. During the tests, split times were also recorded at 1, 2, 3, 4, 5 and 6-m. Based on this, the mean velocity of locomotion in a seated position at particular distances was calculated. Due to the size of the court, the gate placed at the 6^{th} m was considered to be the final one. However, the additional gate placed at the 10^{th}m was to counteract the effect of braking before the finish line and to facilitate any comparison to other research.

Statistical Analysis

The relationships between hand grip strength and movement times were analysed using the Spearman's rank correlation coefficient. The Wilcoxon rank test for pairs was used to determine statistically significant differences between forward and backward locomotion velocity. In addition, a Friedman test for systems with repeated measures (with Kendall's coefficient of concordance) was used to compare values of velocity between particular distances (0-1m, 1-2m, 2-3m, 3-4m, 4-5m, 5-6m and 6-10m). Non-parametric tests were used due to a relatively small number of participants (n = 9).

Results

The mean values (± *SD*) of grip strength measured with the hydraulic dynamometer were 45.2±12.1kG for the right hand and 43.2±15.1kG for the left hand. Spring dynamometer measurements were 46.1±9.9kG and 45.9±13.4kG, respectively. Mean values (± *SD*) of times for sitting volleyball players are presented in Table 2.

There were statistically significant negative correlations between hand grip strength (for the left and the right hand) and mean times of forward movement over a distance of 0-1 m. The relationship between hand grip strength and forward movement times at other sections was not statistically significant. The obtained results are presented in Tables 3 and 4.

No statistically significant correlations between hand grip strength (for the left and the right hand) and mean backward movement times were found for sections 0-1m, 0-2m, 0-3m, 0-4m, 0-5m, 0-6m and 0-10m.

There was no statistically significant effect for forward locomotion velocity (p=.28) and for backward locomotion velocity (p=.27) at particular sections (0-1m, 1-2m, 2-3m, 3-4m, 4-5m, 5-6m and 6-10m). The analysis of the locomotion velocity curve (both forward and backward) revealed an interesting profile characterised by obtaining a locomotion velocity close to the maximal almost at the beginning of the test (already at 1m) and maintenance of it at a relatively constant level up to 10m (Figure 1).

Additionally, there were no statistically significant differences between forward and backward locomotion velocity at sections 0-1m, 1-2m, 2-3m, 3-4m, 4-5m, 5-6m and 6-10m.

Table 1

Anthropometric and training characteristics of sitting volleyball players (mean ± SD).

Group (*n*)	Body height (cm)	Body mass (kg)	Age (years)	Training experience (years)	Sports activity (hours per week)
9	179.2±8.1	79.0±14.8	34.3±16.1	4.3±2.7	9.3±6.1

Table 2

Mean (± SD) times of locomotion in the seated position using the upper and lower extremities in sitting volleyball players.

t (s)	0-1m	0-2m	0-3m	0-4m	0-5m	0-6m	0-10m
forward	0.48±0.11	0.96±0.23	1.43±0.34	1.89±0.45	2.35±0.57	2.81±0.70	4.62±1.27
backward	0.60±0.37	1.07±0.46	1.52±0.53	1.96±0.63	2.43±0.72	2.90±0.83	4.81±1.37

Table 3

Correlation coefficients between right (SRH) and left (SLH) hand grip strength (hydraulic dynamometer) and mean forward movement times ($t_{forward}$) in the seated position for distances of 0-1m, 0-2m, 0-3m, 0-4m, 0-5m, 0-6m and 0-10m.

$t_{forward}$	0-1 m	0-2 m	0-3 m	0-4 m	0-5 m	0-6 m	0-10 m
SRH	-0.73*	-0.58	-0.53	-0.53	-0.57	-0.47	-0.23
SLH	-0.78*	-0.63	-0.58	-0.58	-0.63	-0.50	-0.28

** - statistically significant at p < .05*

Table 4

Correlation coefficients between right (SRS) and left (SLS) hand grip strength (spring dynamometer) and mean forward movement times ($t_{forward}$) for distances of 0-1m, 0-2m, 0-3m, 0-4m, 0-5m, 0-6m and 0-10m.

$t_{forward}$	0-1m	0-2m	0-3m	0-4m	0-5m	0-6m	0-10m
SRS	-0.70*	-0.57	-0.50	-0.50	-0.52	-0.45	-0.20
SLS	-0.75*	-0.60	-0.55	-0.55	-0.60	-0.48	-0.27

**-statistically significant at p<.05*

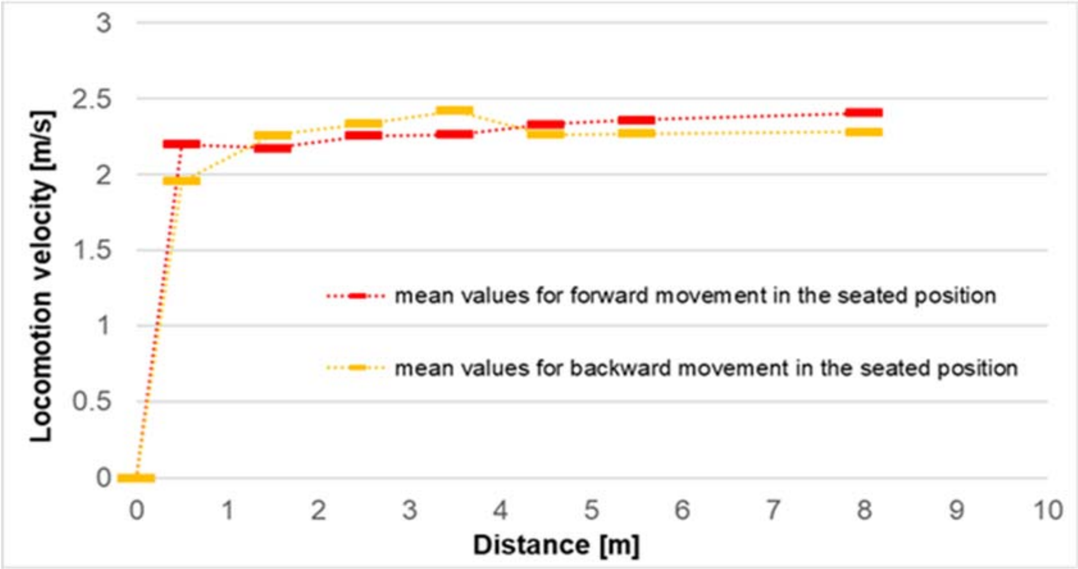

Figure 1

Velocity curves in forward and backward locomotion in a seated position in sitting volleyball players. Points on the diagram indicate mean velocity achieved by athletes at distances of 0-1m, 0-2m, 0-3m, 0-4m, 0-5m, 0-6m and 0-10m.

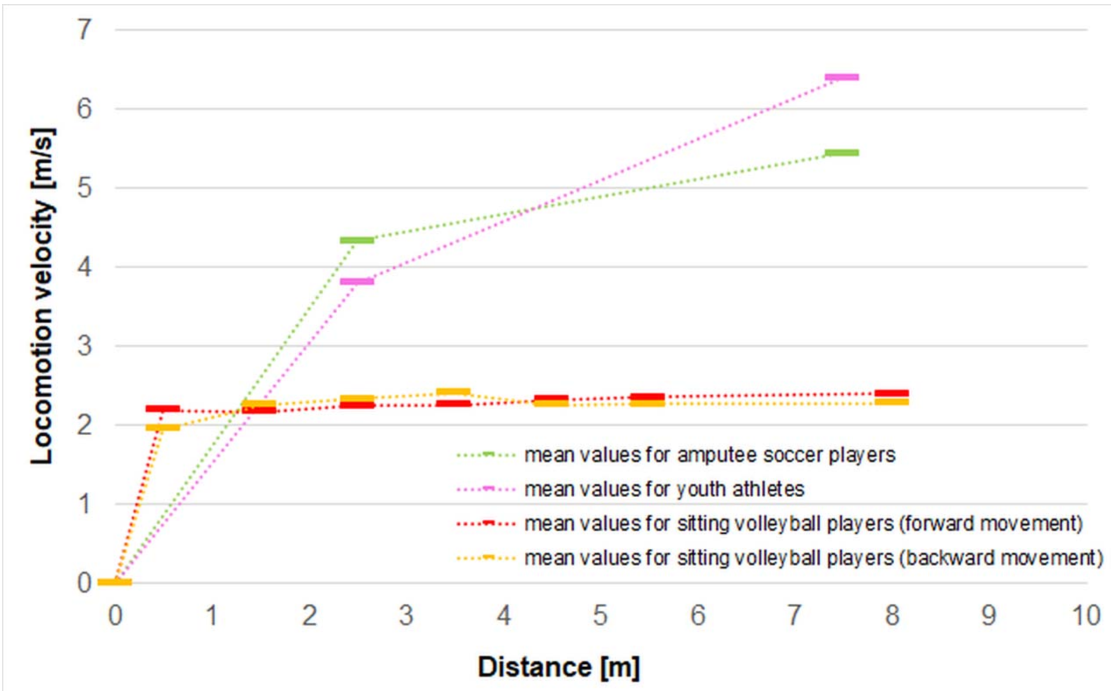

Figure 2

Velocity curves in forward and backward locomotion in the seated position in sitting volleyball players in comparison to running (sprinting) of elite amputee soccer players (Wieczorek et al., 2015) and youth team sport games athletes (Struzik et al., 2015)

Discussion

Greater hand grip strength has a beneficial relationship with forward sitting locomotion speed over a distance of 0-1 m. Therefore, in this area (0-1 m) of considerable activity of sitting volleyball players, the role of the upper limbs in the sitting locomotion is significant. Greater hand grip strength enables players to start their movement by pushing away from the floor using the upper limbs with high vertical pressure exerted on the hands (Zhang et al., 2011) and taking a convenient position to play the ball. This might explain better performance accompanied by shorter times in speed and endurance tests obtained in sitting volleyball players (Jadczak et al., 2010). It is possible that anthropometric variables play a major role as well. Greater arm length, width of the pelvis, upper arm circumference and lower abdominal skinfolds positively influence performance in situational-motor abilities testing in sitting volleyball players (Mahmutović et al., 2015). However, it needs to be mentioned that specific injuries in sitting volleyball players generally linked to the lumbosacral section of the spine, shoulders, arms and fingers (Mustafins et al., 2013) may indicate the importance of the upper half of the body and, in particular, the upper limbs, in game performance (Zwierzchowska et al., 2020).

A decrease in correlation coefficient values between hand grip strength and sitting forward locomotion times with increasing distance was also observed (Tables 3 and 4). This trend may confirm that hand grip strength is an important factor during the start of the sitting movement. At longer distances, other parts of the body and their coordinated motion can also considerably contribute to the forward locomotor efficiency in the seated position.

Sitting volleyball players use the upper extremities for both playing and moving on the court. Hand grip strength in sitting volleyball players was similar to that obtained by elite amputee soccer players who used elbow crutches (Wieczorek et al., 2015) and the population of healthy men (Fernandes et al., 2014). Jadczak et al. (2009) noted that sitting volleyball players with a considerable degree of disability had the highest hand grip strength, which may suggest the involvement of dysfunction compensation in the lower extremities due to high adaptability of strength abilities.

The specificity of locomotion with the use of the upper and lower extremities in the seated position may be responsible for the flat profile of the locomotion velocity curve. It was observed that sitting volleyball players after reaching peak velocity (both backward and forward) at the beginning of the test (at the 1st m) maintained it relatively stable until the end of the distance to be covered (to the 10th m). Although sitting volleyball players move forward and backward in the seated position with a relatively constant velocity, in backward locomotion, peak velocity was achieved later.

Mean times of forward and backward locomotion in the seated position are much longer than those obtained by able-bodied athletes during sprinting (Kaynak et al., 2017; Struzik et al., 2015). The comparison of velocity curves for forward and backward locomotion in sitting volleyball players to sprints of elite amputee soccer players (Wieczorek et al., 2015) and youth athletes (Struzik et al., 2015) is presented in Figure 2.

Much lower peak velocity of forward locomotion in the seated position can be clearly seen compared to that obtained during sprinting by youth healthy athletes and athletes moving with crutches. The relatively low peak velocity of locomotion in the seated position may be the cause of the relatively short acceleration phase, as already more or less at a distance of 1 m, the velocity close to the maximal is obtained. Interestingly, locomotion velocity that is close to the peak value was maintained without a significant decrease to the end of the investigated distance (Little and Williams, 2005). In prepubescent sprinters, the peak running velocity is achieved at a distance between 20 and 30 m (Barr et al., 2013). The movement in the seated position is a completely different type of locomotion compared to running in healthy people or moving on crutches, as evidenced by the velocity curves shown in Figure 2. Therefore, it is necessary to expand the current knowledge about this type of locomotion (Mero et al., 1992).

The present study presents some limitations which should be acknowledged. Future research may consider another variable for the analysis, i.e., the playing position, which, in indoor volleyball, determines the anthropometric characteristics of players (Milić et al., 2017). A small number of participants should also be taken into account (yet, it is extremely difficult to obtain a larger sample size for such a discipline as sitting volleyball). Additionally, hand grip strength measured by means of a dynamometer involves significantly fewer muscles than when moving on the court in the seated position, the locomotor effectiveness of which depends on the coordination of the muscles of the upper and lower extremities and the torso. Hildebrandt et al. (2017) paid attention to the leading role of the strong torso muscles that underpinned sporting achievements by maintaining the correct posture and relieving strain on the passive anatomical structures.

In conclusion, the current study indicates that the level of strength is related to locomotor efficiency of sitting volleyball players. A high level of hand grip strength makes it easier to start moving by pushing away from the ground with the upper limbs.

References

Abadżijew, B. (2014). *Vademecum: sitting volleyball*. Stowarzyszenie Piłki Siatkowej na Siedząco.

Angst, F., Drerup, S., Werle, S., Herren, D. B., Simmen, B. R., & Goldhahn, J. (2010). Prediction of grip and key pinch strength in 978 healthy subjects. *BMC Musculoskeletal Disorders*, *11*(1), 94–99. https://doi.org/10.1186/1471-2474-11-94

Barr, M. J., Sheppard, J. M., & Newton, R. U. (2013). Sprinting kinematics of elite rugby players. *Journal of Australian Strength and Conditioning*, *21*(4), 14–20.

Fernandes, A. A., Natali, A. J., Vieira, B. C., Valle, M. A. A. N., Moreira, D. G., Massy-Westropp, N., & Marins, J. C. B. (2014). The relationship between hand grip strength and anthropometric parameters in men. *Archivos de Medicina del Deporte*, *31*(3), 160–164.

Jadczak, Ł., Kosmol, A., Wieczorek, A., & Śliwowski, R. (2010). Motor fitness and coordination abilities vs. effectiveness of play in sitting volleyball. *Journal of Kinesiology and Exercise Sciences*, *20*(49), 57–67.

Jadczak, Ł., Śliwowski, R., Wieczorek, A., & Wieczorek, J. (2009). The degree of disability and the level of physical fitness and co-ordination abilities of sitting volleyball players. *Polish Journal of Sports Medicine*, *6*(6), 377–385.

Hildebrandt, C., Müller, L., Heisse, C., & Raschner, C. (2017). Trunk strength characteristics of elite alpine skiers - a comparison with physically active controls. *Journal of Human Kinetics*, *57*, 51–59. https://doi.org/10.1515/hukin-2017-0046

Kaynak, K., Eryılmaz, S. K., Aydoğan, S., & Mihailov, D. (2017). The effects of 20-m repeated sprint training on aerobic capacity in college volleyball players. *Biomedical Human Kinetics*, *9*(1), 43–50. https://doi.org/10.1515/bhk-2017-0007

Koley, S., & Bijwe, V. (2014). Correlation of dominant handgrip strength with selected anthropometric variables and performance tests in elite Indian volleyball players. MR *International Journal of Applied Health Sciences*, *1*(1), 58–64.

Leong, D. P., Teo, K. K., Rangarajan, S., Lopez-Jaramillo, P., Avezum Jr, A., Orlandini, A., Seron, P., Ahmed, S. H., Rosengren, A., Kelishadi, R., Rahman, O., Swaminathan, S., Iqbal, R., Gupta, R., Lear, S. A., Oguz, A., Yusoff, K., Zatonska, K., Chifamba, J., … Yusuf, S. (2015). Prognostic value of grip strength: findings from the Prospective Urban Rural Epidemiology (PURE) study. *Lancet*, *386*(9990), 266–273. https://doi.org/10.1016/S0140-6736(14)62000-6

Little, T., & Williams, A.G. (2005). Specificity of acceleration, maximum speed, and agility in professional soccer players. *Journal of Strength and Conditioning Research*, *19*(1), 76–78. https://doi.org/10.1519/14253.1

Mahmutović, I., Delalić, S., Serdar, U., Ibrahimović, M., & Tabaković, A. (2015). Impact of morphological characteristics on the situational-motor abilities of sitting volleyball players. *International Journal of Sport Culture and Science*, *3*(1), 29–33. https://doi.org/10.14486/ijscs226

Marszalek, J., Molik, B., Gomez, M. A., Skučas, K., Lencse-Mucha, J., Rekowski, W., Pokvytyte, V., Rutkowska, I., & Kaźmierska-Kowalewska, K. (2015). Relationships between anaerobic performance, field tests and game performance of sitting volleyball players. *Journal of Human Kinetics*, *48*, 25–32. https://doi.org/10.1515/hukin-2015-0088

Mero, A., Komi, P. V., & Gregor, R. J. (1992). Biomechanics of sprint running: a review. *Sports Medicine*, *13*(6), 376–392. https://doi.org/10.2165/00007256-199213060-00002

Milić, M., Grgantov, Z., Chamari, K., Ardigò, L. P., Bianco, A., & Padulo, J. (2017). Anthropometric and physical characteristics allow differentiation of young female volleyball players according to playing position and level of expertise. *Biology of Sport*, *34*(1), 19–26. https://doi.org/10.5114/biolsport.2017.63382

Molik, B., Kosmol, A., & Skucas, K. (2008). Sport - specific and general sporting physical fitness of sitting volleyball athletes. *Physiotherapy*, *16*(4), 68–75. https://doi.org/10.2478/v10109-009-0047-2

Mustafins, P., Renström, E. P., Vetra, A., Scibrja, I. (2013). Injuries in volleyball for athletes with a disability: a prospective long term study. *Polish Journal of Rehabilitation Research*, *2*(1), 12–18.

Rantanen, T., Guralnik, J. M., Foley, D., Masaki, K., Leveille, S., Curb, J. D., & White, L. (1999). Midlife hand grip strength as a predictor of old age disability. *JAMA*, *281*(6), 558–560. https://doi.org/10.1001/jama.281.6.558

Reddon, J. R., Stefanyk, W. O., Gill, D. M., & Renney, C. (1985). Hand dynamometer: effects of trials and sessions. *Perceptual and Motor Skills*, *61*(3_suppl), 1195–1198. https://doi.org/10.2466/pms.1985.61.3f.1195

Sánchez, A. G., Domínguez, A. S., Turpin, J. A. P., Tormo, J. M. C., & Llorca, C. S. (2011). Importance of hand-grip strength as an indicator for predicting the results of competitions of young judokas. *Archives of Budo*, *7*(3), 167–172.

Struzik, A., Konieczny, G., Grzesik, K., Stawarz, M., Winiarski, S., & Rokita, A. (2015). Relationship between lower limbs kinematic variables and effectiveness of sprint during maximum velocity phase. *Acta of Bioengineering and Biomechanics*, *17*(4), 131-138. https://doi.org/10.5277/ABB-00290-2015-02

Tiainen, K., Sipilä, S., Alen, M., Heikkinen, E., Kaprio, J., Koskenvuo, M., Tolvanen, A., Pajala, S., & Rantanen, T. (2004). Heritability of maximal isometric muscle strength in older female twins. *Journal of Applied Physiology*, *96*(1), 173–180. https://doi.org/10.1152/japplphysiol.00200.2003

Uchmanowicz, I., Lisiak, M., & Jankowska-Polańska, B. (2014). Research instruments used in the assessment of the frailty syndrome. *Polish Gerontology*, *22*(1), 1–8.

Wieczorek, M., Wiliński, W., Struzik, A., & Rokita, A. (2015). Hand grip strength vs. sprint effectiveness in amputee soccer players. *Journal of Human Kinetics*, *48*, 133–139. https://doi.org/10.1515/hukin-2015-0099

Zhang, J. M., Bader, D., Twycross-Lewis, R., & Padhiar, N. (2011). A prospective cohort study of vertical pressure on hands of sitting volleyball players using tekscan pressure mat. *British Journal of Sports Medicine*, *45*(2), e1. https://doi.org/10.1136/bjsm.2010.081554.3

Zwierzchowska, A., Rosołek, B., Celebańska, D., Gawlik, K., & Wójcik, M. (2020). The prevalence of injuries and traumas in elite goalball players. *International Journal of Environmental Research and Public Health*, *17*(7), 2496. https://doi.org/10.3390/ijerph17072496

Corresponding author:

Marta Wieczorek
Wroclaw University of Health and Sport Sciences,
Witelona 25 Street, 51-617 Wrocław, Poland
Phone: +48 885 550 277
E-mail: marta.wieczorek@awf.wroc.pl