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ASSESSMENT OF ASYMMETRICAL LOWER LIMB LOADING IN THE SHORT-TRACK SPEED SKATERS

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Abstract Background. Short-track speed skaters who regularly participate in training are exposed to the occurrence of asymmetry in the lower limb loading.
Objective. The study aimed to assess the symmetry of the lower limb loading in short track skaters and the relationship between age, training experience and anthropometric variables and symmetry of lower limb loading.
Methods. The examined group consisted of 20 short-track speed skaters (12 men and 8 women), and the control group comprised 28 university students (14 men and 14 women). Two scales were used to assess the symmetry of lower limb loading, and the lower limb's loading symmetry index (LSI) was calculated.
Results. In the studied groups 65% of skaters and 82% of students have LSI within the normal range. Most short-track speed skaters (85%) put weight on the right lower limb, and there was no clear trend among students ($p < 0.001$). In the group of skaters, the majority of men (83%) properly loaded their lower limbs, compared to 37.5% of women ($p = 0.036$). In short-track speed skaters, positive correlations were found between LSI and the age and length of training.
Conclusions. Long-term asymmetric loading of the lower limbs in short-track speed skaters causes the advantage of the load on the right lower limb and increases the asymmetry of the load on the lower limbs, especially in women.

Key words: short-track speed skaters, loading symmetry index, asymmetry of lower limb loading

Introduction

Professional sports practice is associated with frequent injuries and overloads (Gallo-Vallejo et al., 2017; Okamura et al., 2014; Osteras et al., 2013). Especially among young athletes, frequent and intense training in a forced position may result in overload changes. Skaters and ice hockey players in the phase of bone growth and shaping body posture are exposed to asymmetry, a curvature of the spine or other overloads (Okamura et al., 2014; Sainz de Baranda et al., 2020).

Short-track speed skating is a form of competitive ice speed skating. In competitions, multiple skaters (typically between four and six) skate on an oval ice track. The speed skaters are only required to skate in a counter clockwise direction – the short track measures 111.12 m. The rink is 60 metres long by 30 metres wide, the same size as an Olympic-sized figure skating rink and an international-sized ice hockey rink. The distances range from 500 m to 5.000 m (Pakosz et al., 2016).

The long track and short track are considered two forms of speed skating – most of the research on speed skating concerns long-track rather than short-track. Long track speed skating is a speed event contested on a 400-meter oval rink with two straightaways and two turns. The much shorter (111.12 m) short-track oval leads to more acute cornering angles and a greater number of corners for comparable distances (Hesford et al., 2012 a). Short-track speed skaters are able to get extremely low to utilise their momentum on turns. That signature hand-on-the-ice technique is also crucial for short-track skaters as they fly around tight corners (van der Kruk et al., 2019). It was shown that after the same training session, short track skaters were more tired than long track skaters, due to competition on a shorter track, with shorter straight sections and tighter turns, differences in intra-muscular pressure and aerobic physiology (Hettiga et al., 2016). There are differences in lower limb asymmetry among short-track speed skaters and long-track speed skaters (Hettiga et al., 2016).

In short track skating, the skater's full attention is focused on the turns where the skaters have to balance the centrifugal force through the gravity of their body. This combined action of centrifugal forces and body weight significantly increases the load on the muscles of the lower extremities. Entering a bend, the skaters try to sit down, and at the end of the bend, there is a centrifugal force that the skaters must balance. Low-skilled short-track skaters stand up, which reduces the speed of movement, and more skilled athletes change the torso angle to the ice to 25–30 °. In doing so, the athlete reaches out with their right arm and leans over the corner to counter the centrifugal force. To keep their balance, their left-hand touch the ice and takes a bend on one foot. These motor actions reduce the buoyancy force's effect, and the time worked out between the fourth and sixth chips leads to the addition of forces (centrifugal and gravity) and contributes to further gaining speed (Ashanin et al., 2021).

Short-track speed skaters who regularly participate in training are exposed to the occurrence of asymmetry in the load on the lower limbs (Pakosz et al., 2016). Prolonged adoption of a forced, often asymmetrical body position may also disturb postural stability and balance. Bilateral asymmetry has been a predictor of injury (Croisier et al., 2008) and largely influence sports performance (Menzel et al., 2012).

The study aimed (1) to assess lower limb loading symmetry index (LSI) in short-track speed skaters (men and women) and compare them to non-training people, and (2) to assess the relationship between age, training experience and anthropometric variables and lower limbs loading symmetry index.

Material and Methods

Study design and setting

The research was conducted in March 2019 at the AZS University Club of the Opole University of Technology and students from the University of Opole in Poland. The research was carried out under the Declaration of Helsinki and Good Clinical Practice guidelines. The Bioethical Commission approved all procedures at Opole Medical School (permission no KB/166/FI/2019). The STROBE guidelines (Strengthening the Reporting of Observational Studies in Epidemiology) were followed.

Participants

A total of 48 participants took part in the study. In the first group were 20 short-track speed skaters (12 male and 8 female) from the Academic Sports Association of the Opole University of Technology. The inclusion criteria were (1) being an active short-track speed skater, (2) having a minimum of one year of experience in short-track, and (3) voluntary consent to participate in the study. The control group consisted of 28 physiotherapy students (14 male and 14 female) from the University of Opole. The inclusion criteria were (1) professional not practising any sports discipline and (2) voluntary consent to participate in the study. Exclusion criteria for both groups included (1) infection or disease within the last two weeks, (2) injury within the last four weeks, which could affect the balance and stability of the participant's posture, and (3) lack of consent to participation in the study.

Methods

The height and body mass were measured, and the Body Mass Index (BMI) was calculated. The age and number of years of training were determined. In order to assess the lower limb loading symmetry, a test of two scales was performed. Two identical BISK bathroom scales with a digital display, enabling measurement with an accuracy of 0.1 kg, were used for the test, which had been previously calibrated so that the test was performed correctly. The participants were in a standing position, with their feet evenly spaced on two scales standing next to each other, with the upper limbs lowered along the body and the eyes directed straight ahead. The participants did not have any jewellery, watches or other things that could distort the study results. The load results for each limb were recorded. Loading symmetry index (LSI) was calculated as the quotient of the greater to the lower value. The correct value ranges from 1.00–1.15 (Czesak et al., 2011).

Additionally, before the measurements, the participants were asked to provide information about which leg they kicked the ball. This question was asked to compare the result given in qualitative form provided by the study based on their experience, a simple test result: in an upright, relaxed, standing position, participants were asked to: kick the dropping paper ball. The experiment was repeated three times. The leg that made the kick was found to be a functionally dominant lower limb, and all skaters had a dominant right leg. The control group included students also with the dominant right leg.

Statistical methods

Descriptive statistics were calculated – mean (M), median (Me), standard deviation (SD), lower (Q1) and upper (Q3) quartile. The distribution of variables was assessed for normality using the Shapiro-Wilk test. Non-parametric methods were used. The Mann-Whitney U-test was used to assess the significance of differences between short-track speed skaters and students. The results of qualitative scales in the analysed groups were compared by chi^2 of non-parametric Spearman's rank correlation coefficient was used to assess the relationship between age, training experience, anthropometric variables, and the lower limb loading symmetry index. The calculations were made in the Statistica 13.3 program (TIBCO Inc., Tulsa, the United States). The level of $p \leq 0.05$ was adopted for the assessment of statistical significance.

Results

Descriptive data

The short-track speed skaters were younger than the students ($p < 0.001$). The median of experience was 6.00 years (table 1).

Table 1. Characteristics of the short-track skaters and students

Variables	Group	M ±SD	Me	Q1 – Q3	Z	p
Age [years]	short-track skaters	18.80 ±5.77	17.5	14.5 – 21.5	**–3.387**	**<0.001**
	students	22.39 ±1.44	22.0	22.0 – 23.0		
Body height [cm]	short-track skaters	167.05 ±13.79	169.5	158.5 – 179.5	–1.714	0.086
	students	174.46 ±7.33	174.00	22.00 – 23.00		
Body mass [kg]	short-track skaters	63.74 ±15.20	63.45	54.50 – 75.35	–1.495	0.134
	students	71.37 ±13.16	72.00	59.50 – 81.00		
BMI [kg/m^2]	short-track skaters	22.47 ±2.49	21.78	20.74 – 23.51	–0.721	0.470
	students	23.31 ±3.19	22.86	20.76 – 25.21		
Years of professional experience [years]	short-track skaters	7.60 ±5.45	6.00	3.50 – 9.50	–	–

Note: M – mean; SD – standard deviation; Me – median; Q1 – lower quartile; Q3 – upper quartile
Z – the value of the Mann-Whitney test used when the size of both groups is greater than 20, p – significance level of the Z test, statistically significant differences ($p \leq 0.05$) were marked in bold

Main results

In the studied groups 65% of short-track speed skaters and 82% of university students have LSI within the normal range. The differences between the groups were not statistically significant (Table 2). Most short-track speed skaters (85%) put their weight on the right lower limb, then 10% on the left lower limb, and 5% on both limbs equally. A greater proportion of students (43%) put a burden on the left lower limb (43%), the right lower limb (28.5%) or the same load (28.5%). The difference between the groups was statistically significant ($p < 0.001$) (table 2).

Table 2. LSI and distribution of load among short-track skaters and students

Variables		Short-track skaters n (%)	Students n (%)	Chi2
LSI	1 ≤ 1.15	13 (65%)	23 (82%)	Chi2 = 0.195 p = 0.183
	>1.15	7 (35%)	5 (18%)	
Distribution of load	P > L	17 (85%)	8 (28,5%)	Chi2 = 0.536 **p < 0.001**
	L > P	2 (10%)	12 (43%)	
	P = L	1 (5%)	8 (28,5%)	

Note: LSI – loading symmetry index, R rang Spearman's, statistically significant differences ($p \leq 0.05$) were marked in bold

When comparing the load on the limbs of both sexes in short-track speed skaters, the majority of men (83%) use proper load on the lower limbs compared to women (37.5%). The difference between men and women was statistically significant (p = 0.036). In women, there was more asymmetry in the load on the lower extremities. Among students, the difference between the sexes in the load on the lower limbs was not statistically significant (p = 0.149). (table 3).

Table 3. Distribution of load on the lower limbs among short-track skaters and students

Variable Women n (%)		Short-track skaters			Students		
		Men n (%)	Chi2	Women n (%)	Men n (%)	Chi2	
LSI	1 ≤ 1.15	3 (37,5%)	10 (83%)	Chi2 = –0.470	10 (71,5%)	13 (93%)	Chi2 = –0.279
	>1.15	5 (62,5%)	2 (17%)	**p = 0.036**	4 (28,5%)	1 (7%)	p = 0.149

Note: LSI – loading symmetry index, R rang Spearman's, statistically significant differences (p ≤ 0.05) were marked in bold

Among short-track speed skaters and students, the LSI index was on a similar level. The differences were not statistically significant (table 4).

Table 4. Descriptive statistics for LSI among short-track skaters and students

Variable	Group	M ±SD	Me	Q1 – Q3	Z	p
LSI	short-track skaters	1.11 ±0.08	1.09	1.03 – 1.17	1.746	0.080
	students	1.07 ±0.07	1.04	1.00 – 1.12		

Note: LSI – loading symmetry index; M – mean; SD – standard deviation; Me – median; Q1 – lower quartile; Q3 – upper quartile; Z – Mann-Whitney test value used when the size of both groups is greater than 20, p – significance level of the Z test

Short-track speed skaters found moderate positive correlations between LSI and age (0.509) and length of training (0.465). Older age and longer training experience increase the asymmetry of the load on the lower limbs. The relationships between anthropometric variables and LSI were not statistically significant. There were no statistically significant correlations among students between age, anthropometric variables and LSI (table 5).

Table 5. Correlations between LSI and age, years of training and anthropometric variable

Group	Variables	Age [years]	Years of training	BH [cm]	BM [kg]	BMI [kg/m^2]
Short-track skaters	LSI	**0.509**	**0.465**	0.075	0.100	0.066
Students	LSI	0.060	–	–0.157	–0.300	–0,347

Notes: BH – body height, BM – body mass; BMI – body mass index; LSI – loading symmetry index; statistically significant correlations (p ≤ 0.05) were marked in bold

Discussion

The study aimed to assess the symmetry of the load on the lower limbs in short-track speed skaters and to compare it to non-training people. It was found that a slightly larger and more frequent asymmetry of lower limb load concerns short-track speed skaters than students. Since the difference between the groups regarding the frequency of the correct load and the average load size is not statistically significant, we can only talk about the tendency to asymmetry in the load on the lower limbs of short-track speed skaters.

There is a difference in the symmetry of load on the lower limbs in short-track speed skaters between genders, and load end asymmetry occurs in 62.5% of women and 17% of men. Greater susceptibility to training loads and the associated asymmetry of lower limb load in women may be associated with differences in anatomical structure and physiology between women and men. Men have more muscle mass than women; they are also taller and heavier than women (Kanehisa et al.,1994; Podstawski et al., 2022; Stefani, 2006). Men also have greater strength and power than women (Kanehisa, Ikegawa, Fukunaga, 1994; Podstawski et al., 2022). Women's tendon structures are less resistant to stretching than men's (Kubo et al.2003). The gender differences in athletes increase with age (Podstawski et al., 2022; Lepers et al., 2013; Senefeld et al., 2016).

The study also found a statistically significant advantage of loading the left lower limb among short-track speed skaters. This is probably due to constantly driving to the left during training and competition on a small track and putting more weight on the left limb. Asymmetry can hugely impact the body's performance and cause changes in the work of muscles harmful to the athlete, while their shortening and stretching are considered a factor contributing to the occurrence of an injury. Monitoring the asymmetry is aimed at assessing the effectiveness of rehabilitation and obtaining information on when the player can return to sports (Pakosz et al., 2016). There is little research into postural asymmetry or overload in short-track speed skaters. Hesford et al. (2012 b) showed that short-track speed skaters while making high-speed unilateral turns, tend to have a significant asymmetry between the local levels of desaturation of the quadriceps muscles of the lower right and left limbs. In the case of skaters riding during a turn on the right lower limb, there was a decrease in blood volume in the muscle, while in the left lower limb, an increase was observed. Researchers also showed that the saturation of the tissues of the right and left lower limb muscles during the race initially decreases sharply. Then, in the right lower limb, the level of desaturation remains relatively constant, while in the left limb, desaturation gradually returns to its pre-race state (Hesford et al., 2012 b). The asymmetric work of the lower limb muscles in the Polish women's short track team was described by Konieczny et al. (2020). All skaters showed higher myoelectric fatigue symptoms in the right gluteal great muscle than in the left one. This phenomenon was not observed in untrained people who had, on average, similar myoelectric fatigue symptoms in both legs (Konieczny et al., 2020).

Skaters in short track race counter clockwise, with only left-hand turns. Training should thus be planned to minimise the asymmetry in skaters despite the typically asymmetrical muscle work during training on ice and competition; thus, new training protocols should be developed or considered to decrease that asymmetry. Such a solution may be training in both directions to balance muscle development and improve coordination.

The study's second aim was to assess the relationship between age, training experience, anthropometric variables and LSI. A significant, moderate correlation between age and training experience and LSI was found in the group of short-track skaters. It can be concluded that the older the skater and the longer the training period, the greater the asymmetry of the lower limb loading. Probably long-lasting training and competition loads translate into increased asymmetry. This asymmetry helps skaters achieve better results in sports, but it should be safe enough not to interfere with everyday life and other sports functioning.

Limitations

The study also has limitations. A small number of short-track speed skaters from only one club were examined. However, a coherent group of athletes who had uniform training. Another limitation is the insufficient exclusion criteria. The imbalance and asymmetry of the lower limbs may be affected by injuries and overloads that occurred much earlier than four weeks before the examination. Thus, the exclusion criteria should include a longer time from the injury. Also, pain and overload of the musculoskeletal system should exclude competitors from participating in the study. The respondents should also be instructed to refrain from intense physical effort one day before the test so that muscle fatigue does not affect the test result.

Further Research

Further research should consider a much larger number of short-track speed skaters, both men and women, as well as the relationship between lower limb loading asymmetry index and the symmetry of the spine, musculoskeletal disorders and the frequency of injuries. Future research should also include more precise exclusion criteria.

Practical Implication

By monitoring the lower limb loading, a coach could also obtain more information on how to individualize loads for skaters. In addition, results of the research, may help coaches and athletes, as well as doctors, physiotherapists, and scientists in planning training in order to prevent asymmetry and decrease the risk of injury.

Conclusion

Skating on a short track increases the asymmetry of load on the lower limbs in females. Long-term asymmetric loading of limbs in short-track speed skaters causes the load on the left lower limb. Age and a greater number of years of experience increase the asymmetry of lower limb loading. Training sessions should be planned in such a way as to minimise the risk of asymmetry in skaters.

References

Ashanin, V., Dolgopolova, N., Dolgopolova, M., Filenko, L., & Pasko, V. (2021). Biomechanical analysis of motional actions of athletes engaged in short track speed skating during the turning phase. *Archiv of Slob. herald of science and sport*, *9*(5), 92–107.

Croisier, J. L., Ganteaume, S., Binet, J., Genty M., & Ferret, J. M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *The American Journal of Sports Medicine*, *36*(8), 1469–1475. https://doi.org/ 10.1177/0363546508316764

Czesak, J., Szczygieł, A., & Żak, M. (2011). Wpływ postępowania fizjoterapeutycznego na wskaźnik symetryczności obciążenia kończyn dolnych u osób po 65. roku życia – badanie pilotażowe [Effects of physiotherapy on the loading symmetry index (LSI) in patients over 65 years old – pilot study]. *Gerontologia Polska, 19*(3–4), 171–175.

Gallo-Vallejo, M. Á., de la Cruz-Márquez, J. C., de la Cruz-Campos, A., de la Cruz-Campos, J. C., Pestaña-Melero, F. L., Carmona-Ruiz, G., & Gallo-Galán, L. M. (2017). Sports injuries and illnesses during the Granada Winter Universiade. *BMJ Open Sport & Exercise Medicine*, *2*(1), e000123. https://doi.org/ 10.1136/bmjsem-2016-000123

Hesford, C. M., Laing, S. J., Cardinale, M., & Cooper, C. E. (2012 a). Asymmetry of quadriceps muscle oxygenation during elite short-track speed skating. *Medicine & Science in Sports & Exercise*, *44*(3), 501–8. https://doi.org/ 10.1249/MSS.0b013e31822f8942

Hesford, C., Laing, S., Cardinale, M., & Cooper, C. E. (2012 b). Effect of Race Distance on Muscle Oxygenation in Short-Track Speed Skating. *Medicine and Science in Sports and Exercise, 45*(1), 83–92. https://doi.org/ 10.1249/MSS.0b013e31826c58dd

Hettinga, F. J., Konings, M. J., Cooper, C. E. (2016). Differences in Muscle Oxygenation, Perceived Fatigue and Recovery between Long-Track and Short-Track Speed Skating. *Frontiers in Physiolology*, *7*, 619. https://doi.org/ 10.3389/fphys.2016.00619

Kanehisa, H., Ikegawa, S., & Fukunaga, T. (1994). Comparison of muscle cross-sectional area and strength between untrained women and men. *European Journal of Applied Physiology, 68*, 148–154. https://doi.org/ 10.1007/BF00244028

Konieczny, M., Pakosz, P., & Witkowski, M. (2020). Asymmetrical fatiguing of the gluteus maximus muscles in the elite short-track female skaters. *BMC Sports Sciences, Medicine and Rehabilitation, 12*, Article e48. https://doi.org/ 10.1186/s13102-020-00193-w

Kubo, K., Kanehisa H., & Fukunaga, T. (2003). Gender differences in the viscoelastic properties of tendon structures. *European Journal of Applied Physiology, 88*, 520–526. https://doi.org/ 10.1007/s00421-002-0744-8

Lepers, R., Knechtle, B., & Stapley, P. J. (2013). Trends in Triathlon Performance: Effects of Sex and Age. *Sports Medicine*, *43*(9), 851–63. https://doi.org/ 10.1007/s40279-013-0067-4

Menzel, H. J., Chagas, M. H., Szmuchrowski, L. A., Araujo, S., de Andrade, A. G., de Jesus-Moraleida, F. R. (2012). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *The Journal of Strength and Conditioning Research, 27*(5), 1370–1377. https://doi.org/ 10.1519/JSC.0b013e318265a3c

Okamura, S., Wada, N., Tazawa, M., Sohmiya, M., Ibe, Y., Shimizu, T., Usuda, S., & Shirakura, K. (2014). Injuries and disorders among young ice skaters: relationship with generalized joint laxity and tightness**.** *Open Access Journal of Sports Medicine, 5*, 191–195. https://doi.org/ 10.2147/OAJSM.S63540

Osterås, H., Garnæs, K. K., & Augestad, L. B. (2013). Prevalence of musculoskeletal disorders among Norwegian female biathlon athletes. *Open Access Journal of Sports Medicine, 4*, 71–78. https://doi.org/ 10.2147/OAJSM.S41586

Pakosz, P., Jakubowska-Lukanova, A., & Gnoiński, M. (2016). TMG as a prevention method of athletes muscles, ligaments and joints injuries. *Polish Journal of Sports Medicine, 3*(4), 189–200. https://doi.org/ 10.5604/1232406X.1227534

Podstawski, R., Borysławski, K., Katona, Z. B., Alföldi, Z., Boraczyński, M., Jaszczur-Nowicki, J., & Gronek, P. (2022). Sex Differences in Anthropometric and Physiological Profiles of Hungarian Rowers of Different Ages. *International Journal of Environmental Research and Public Health*, *19*(13), 8115. https://doi.org/ 10.3390/ijerph19138115

Sainz de Baranda, P., Cejudo, A., Moreno-Alcaraz, V. J., Martinez-Romero, M. T., Aparicio-Sarmiento, A., & Santonja-Medina, F. (2020). Sagittal spinal morphotype assessment in 8 to 15 years old Inline Hockey players. *PeerJ*, *8*, e8229. https://doi.org/ 10.7717/peerj.8229

Senefeld, J., Joyner, M. J., Stevens, A., & Hunter, S. K. (2016). Sex differences in elite swimming with advanced age are less than marathon running. *Scandinavian Journal of Medicine & Science in Sports*, *26*(1), 17–28. https://doi.org/ 10.1111/sms.12412

Stefani, R. T. (2006). The relative power output and relative lean body mass of World and Olympic male and female champions with implications for gender equity. *Journal of Sports Science*, *24*, 1329–1339. https://doi.org/ 10.1080/02640410500520559

van der Kruk, E., Reijne, M. M., de Laat, B., & Veeger, D. H. E. J. (2019). Push-off forces in elite short-track speed skating. *Sports Biomechanics*, *18*(5), 527–538. https://doi.org/ 10.1080/14763141.2018.1441898

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