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DOES PADDLING IN CANOES CAUSE ASYMMETRY OF MUSCLE MASS AND FAT MASS IN HIGH LEVEL ATHLETES?

Introduction

Symmetry means commensurability and is one of the basic structural features of most plants and animals (Encyclopaedia PWN 2010). Most tissues are characterized by bilateral symmetry, where the long axis of the body corresponds to the axis of symmetry. Therefore, both sides of the body consist of two identical parts. Asymmetry means a deviation from the line of symmetry: in the case of human beings, there are differences in the structure between the left and right sides of the body. The human body seems to be symmetrical, however, the distribution of internal body organs is asymmetric (Wolański 1975). Also, the structure of movement is far from symmetry because in the early stages of life one upper limb begins to dominate (Foreman 2008). Also, the body structure may be asymmetrical, which may be related to external factors (Sanchis-Moysi et al 2004; Kazunori et al. 2006). In the area of human movements, one distinguishes functional and dynamic asymmetry (Starosta 2008). Asymmetry can be observed in numerous for-

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mally symmetrical activities, such as walking (Cavanagh 1990; Belli et al. 1995).

Asymmetry of human movements, i.e. functional asymmetry and dynamic asymmetry, may cause asymmetry of the body structure (also known as structural asymmetry). Uneven development of muscle mass may cause disorders of posture and, as a consequence, lead to negative changes in the skeletal system (Peters 1988; Moreno et al. 2002). It was found that during a jump the power and strength of the lower limbs is asymmetrical within 6% in football players (Impellizzeri et al. 2007) and up to 10% in physically active people (Benjanuvatra et al. 2013). Additionally, the asymmetry of muscle strength in the lower limbs is associated with a high risk of injury (Impellizzeri et al. 2007; Knapik et al. 1991). It has been shown that in 20-25% power asymmetry of the lower limbs is related to the asymmetry of lean body mass (Bell et al. 2015).

Numerous studies addressing asymmetry can be found in the literature, but only a few papers concern asymmetry caused by canoeing (Rynkiewicz and Starosta 2011). Canoeing is a sports discipline which requires a high level of preparation, especially in terms of endurance, strength, and coordination of movements (Rynkiewicz 2009). In classic canoeing – flatwater, competitors paddle in kayaks or in canoes. Paddling in a kayak requires symmetric movements. On the other hand, in a canoe, paddlers perform asymmetrical moves because they kneel on one knee in a lunge position, and paddle only on one side (Fig. 1). Adopting such a position is connected with the asymmetric tension of the muscles of the lower limbs and, during paddling, asymmetrical loading of the trunk and the upper limbs because the muscles on the opposite sides of the longitudinal axis of the body fulfill completely different functions (Rynkiewicz and Starosta, 2011). As a result, this action can cause asymmetric muscle hypertrophy.

In sports training for canoeists, symmetrical exercises are also used, such as gym and running exercises. About 50% of the training load is paddling (Rynkiewicz 2009). As a result, asymmetry can be observed, which can often adversely affect sports results, and may at a later age influence negatively a competitor's health.

Therefore, this study aimed to determine whether paddling in a canoe causes muscle mass asymmetry. It was assumed that the effect of long-term uneven loading of the limbs on the right and left sides of the body will be visible during a segmental body composition analysis.



Figure 1. A competitor while paddling a canoe.

Source: own study.

Materials

The research involved 40 athletes who train canoeing and specialize in paddling in canoes. The athletes' sports level was between the second and the championship international sports class. The training period of the respondents was between 2 and 10 years. The subjects were divided into 2 groups: the first group (A) consisted of 21 competitors with the training experience of 3 years or fewer; the second involved athletes with the experience of at least 7 years. In the P group, there were athletes at a very high sports level, including one Olympian and 18 athletes who at least once competed in the world championships. The basic characteristics of their body structure are shown in Table 1.

Table 1

Physique characteristics of the tested athletes with the division into beginners and advanced n=40

Group	Value	Age [years]	Body height [cm]	Body mass [kg]	Body fat [%]
A n=21	M \pm SD	14.05 \pm 0.86	175.64 \pm 8.15	65.13 \pm 10.46	15.76 \pm 2.12
	Min-Max	12.0-16.0	159.5-185.0	50.1-86.7	12.0-21.8
P n=19	M \pm SD	20.89 \pm 3.25	180.32 \pm 7.50	79.74 \pm 7.03	10.29 \pm 3.65
	Min-Max	17.0-31.0	164.0-193.0	68.5-93.1	5.3-16.2

Source: own study.

Test methods

The measurement of body height was performed using a standard wall height altimeter. The measurement accuracy was 0.5 cm. The measurement of body weight and its composition was performed using the electrical bioimpedance method. For this purpose, the Tanita MC780 analyzer (Japan) was used, in which different frequencies were used for the measurement, which significantly improves the obtained results (Salmi 2003). All the measurements were taken between 7:00 and 7:30 am. The athletes were awoken; then, having used the toilet, participated in the measurements. The subjects were fasting during the study. Next, the data on the content of muscle mass, fat mass, as well as segmental content of the left and right upper muscle mass (MMPKG and MMLKG), right and left lower limbs (MMPKD and MMLKD), and muscle mass of the torso (MMT) were obtained. The fat mass for the right and left upper limbs (TTPKG and TTLKG), right and left lower limbs (TTPKD and TTLKD), and trunk (TTT) were also determined.

On the basis of the results obtained, mean values and standard deviations were calculated. The Lillefors test and Shapiro-Wilk test helped assess the normality of the distribution of the studied characteristics. Since the variables were characterized by normal distribution, the T test was used to calculate the significance of differences between both groups. The asymmetry index was calculated for the absolute values of muscle mass and fat mass in the upper and lower limbs. The following formula was used to calculate the asymmetry indicators:

$$WA = \frac{X_p - X_l}{\frac{(X_p + X_l)}{2}} * 100\%$$

(Rynkiewicz 2003, Bell et al. 2014).

Results

On the basis of the analysis performed, it was found that both groups differed significantly from each other. The P athletes were older, heavier, characterized by lower adipose tissue content and higher muscle mass content than the competitors from group A. The body building values for the competitors from both groups are shown in Table 2.

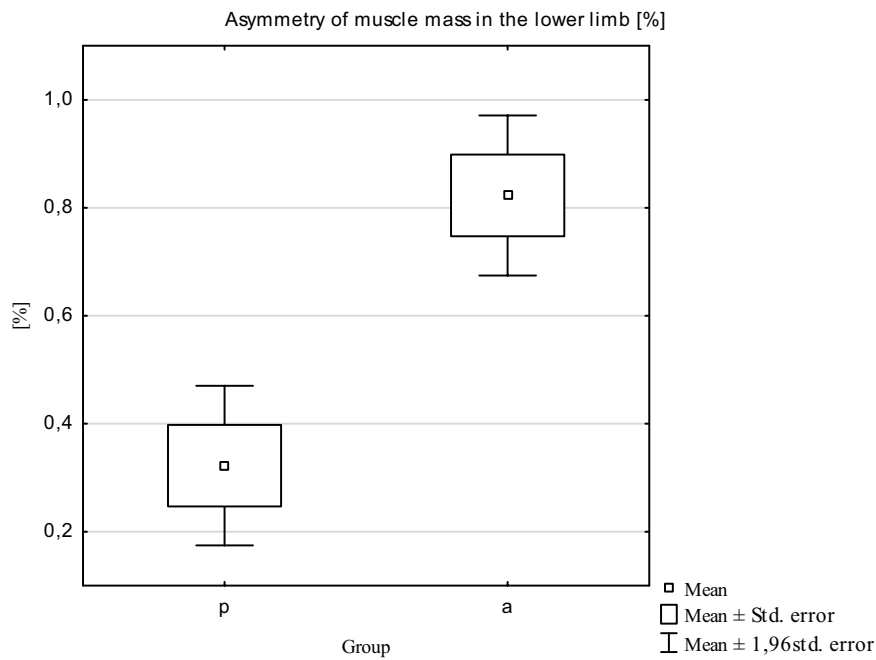


Figure 2. Mean values of muscle mass asymmetry of the lower limbs [%] in the studied groups P [n=19] and A [n=21].

Source: own study.

Based on the tests on the significance differences, it may be stated that a higher level of muscle mass asymmetry in the lower limbs was found in the athletes from group A (Table 2). In other cases, the differences were not statistically significant. A noticeable difference was observed in the case

of asymmetry of the lower limbs fat mass, where the P group were more asymmetric, but the level of significance was 8% and the differences were not statistically significant.

Table 2

List of mean values of the examined characteristics in groups P and A, and p values for the significance tests on the differences between groups P [n=19] and A [n=21]

	Group P	± SD	Group A	± SD	t	Level of significant differences p
Age [years]	20.89	3.25	14.05	0.86	9.32	0.00
Body high [cm]	180.32	7.50	175.64	8.15	1.88	0.07
Body mass [kg]	79.74	7.03	65.13	10.46	5.13	0.00
Body fat [%]	10.29	3.65	15.76	2.12	-5.87	0.00
Fat mass [kg]	7.73	2.93	10.35	2.72	-2.94	0.01
Muscle mass [kg]	67.96	6.18	52.01	7.85	7.08	0.00
BMI	24.53	1.69	21.12	2.26	5.35	0.00
MMLKG [kg]	4.42	0.54	2.74	0.49	10.32	0.00
MMPKG [kg]	4.39	0.56	2.70	0.47	10.34	0.00
WA MMKG [%]	0.63	0.56	0.54	0.60	0.47	0.64
MMLKD [kg]	11.22	1.02	8.90	1.50	5.62	0.00
MMPKD [kg]	11.29	0.92	9.18	1.51	5.27	0.00
WA MMKD [%]	0.32	0.33	0.82	0.35	-4.67	0.00
MMT [kg]	36.62	3.33	28.49	4.01	6.94	0.00
TTLKG [kg]	0.41	0.19	0.77	0.15	-6.54	0.00
TTPKG [kg]	0.44	0.13	0.66	0.14	-5.14	0.00
WA TTKG [%]	4.02	4.65	3.89	2.53	0.12	0.91
TTLKD [kg]	1.77	0.52	2.62	0.66	-4.48	0.00
TTPKD [kg]	1.76	0.52	2.63	0.65	-4.64	0.00
WA TTKD [%]	1.00	1.30	0.45	0.50	1.77	0.08
TTT [kg]	3.88	2.06	3.68	1.32	0.38	0.71

Source: own study.

Discussion

Paddling in a canoe is a very asymmetrical activity because completely different movements are performed on both sides of the body. A competitor in canoeing strokes on one side of the canoe up to 3500-4500 km during an annual training cycle (Rynkiewicz 2009). Such repeated asymmetrical muscle tone may cause asymmetries in the body structure (Hawrylak et al. 2001, 2008; Sławińska et al. 2006; Ciechanowska and Hagner 2007). This phenomenon seems to be extremely harmful and may lead to the deterioration of health in athletes.

Furthermore, the choice of the paddling side has no theoretical justification. Competitors are selected on the basis of the current needs: in order to complete a two-person settlement, one has to choose athletes paddling on opposite sides of the boat (Rynkiewicz 2009). The functional domination of one side of the body has long been confirmed among societies. One can talk thus about the domination of one upper and one lower limb, as well as of one eye. In the Polish population, the majority of people are right-handed (Starosta 2008). In the case of paddling in canoes, it is irrelevant whether the upper or lower limb is dominant. Right- and left-handed persons as well as those with different domination of the right and left lower limbs can paddle on the right side. The domination of one side of the body is linked to the dominance of one of the cerebral hemispheres, but the details of this relationship have not been investigated so far (Bryden and Kay 2002). It is assumed that the dominant hand is responsible for pre-planned movements, while the opposite hand for stabilizing (Sainburg 2005). It is unknown whether paddling on the dominant side or on the opposite side can influence positively the achievement of high sports results or athletes' health.

In the available literature, there are no studies addressing this issue in relation to athlete paddling in a canoe. Therefore, it seemed necessary to investigate whether paddling in a canoe can increase asymmetry of muscle mass.

On the basis of the obtained results, it was not possible to confirm the hypothesis that paddling in a canoe causes asymmetry in the distribution of muscle mass and fat mass (Table 2). Furthermore, the data seem to show the opposite tendency as lesser asymmetry in muscle mass of the lower limbs was observed in the advanced competitors than in the competitors who started their adventure with canoes (Figure 1).

This may be caused by a properly conducted general development training, which in fact leads to the reduction of asymmetry that may have resulted from biological development in young athletes. It is also possible that the training used in young athletes consisted largely of specialist work,

which in effect led to muscle mass asymmetry.

During weight training, adult paddlers are subjected to significant loads, which to a large extent stimulate the development of muscle mass (Platonov 2004). They are symmetrical loads. In specialist training, endurance loads are used, they stimulate only weakly the development of muscle mass. The use of strength training could lead to an even development of muscle mass on both sides of the body.

A completely different situation was observed in the fat tissue distribution in the lower limbs, where the more experienced competitors showed asymmetry, but the differences were not statistically significant (Table 2). Long-term specialist loads may have caused a lower level of fat mass, however, the level of asymmetry in this case was minimal: it was 0.45% for group A and 1% for group P.

Conclusion

Despite asymmetrical loads on the muscular system, long paddling in a canoe does not increase asymmetry of muscle mass. Furthermore, it can be assumed that a long-term training helps to equalize muscle mass in the lower limbs.

Literature

- BELL D. R., SANFILIPPO J. L., BINKLEY N., HEIDERSCHEIT B. C. (2015), *J Strength Cond Res.* 2014 Apr, 28(4), pp. 884-891.
- BELLI A., LACOUR J. R., KOMI P. V., CANDAU R., DENIS C. (1995), Mechanical step variability during treadmill running. *Eur J. Appl Physiol*, 70, pp. 510-517.
- BENJANUVATRA N., LAY B. S., ALDERSON J. A., BLANKSBY B. A. (2013), Comparison of ground reaction force asymmetry in one- and two-legged countermovement jumps, *J Strength Cond Res.*, 27, pp. 2700-2707.
- BRYDEN P. J., KAY C. A. (2002), Hand preference in simultaneous uni- manual tasks: A preliminary examination. *Brain and Cognition*, 48, pp. 284-287.
- CAVANAGH P. R. (1990), Biomechanics: a bridge builder among the sport sciences, *Med Sci Sports Exerc*, 22, pp. 546-557.
- CIECHANOWSKA K., HAGNER W. (2007), Skoliozy u wioślarzy trenujących na długich wiosłach, "Kwartalnik Ortopedyczny", 65, pp. 26-29.

- HAWRYLAK A., SKOLIMOWSKI T., BARCZYK K., BIEĆ E. (2001), Asymetria w obrębie tułowia u osób trenujących wyczynowo różne dyscypliny sportu, *Med. Sport*, 6, pp. 232-235.
- HAWRYLAK A., SKOLIMOWSKI T., BARCZYK K., RATAJCZAK B. (2008), Asymetria tułowia osób z dyskopatią odcinka lędźwiowego kręgosłupa na poziomie L5-S1, *"Fizjoterapia Polska"*, 8,1, pp. 11-22.
- IMPELLIZZERI F. M., RAMPININI E., MAFFIULETTI N., MARCORA S. M. (2007), A vertical jump force test for assessing bilateral strength asymmetry in athletes, *Med Sci Sports Exerc.*, 39(11), pp. 2044-50.
- KAZUNORI I., KOICHI N., KAZUNORI I., HIDEO F., HIROYUKI N. (2006), Low back pain and lumbar disc degeneration are related to weight category in collegiate wrestlers, *"Medicine and Science in Sports and Exercise"*, 38(5), Supplement: 51.
- KNAPIK J. J., BAUMAN C. L., JONES B. H., HARRIS J. M., VAUGHAN L. (1991), Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes, *Am J Sports Med.*, 19, pp. 76-81.
- MORENO L. A., RODRIGUEZ G., GUILLEN J., RABANAQUE M. J., LEÓN J. F., ARIÑO A. (2002), Anthropometric measurements in both sides of the body in the assessment of nutritional status in pre-pubertal children, *Eur. J. Clin. Nutr.*, 56(12), pp. 1208-1215.
- PETERS M. (1988), Footedness: asymmetries in foot preference and skill and neuropsychological assessment of food movement, *Psych. Bull.*, 103, pp. 179-192.
- PLATONOV V. N. (2004), Sistema podgotovki sportsmenov v olimpijskom spor-te. Obszczaja teorija i jej prakticeskije prilozenija. Olimpijskaja literatura, Kiev.
- PWN (2010), Encyklopedia, www.pwn.pl.
- RYNKIEWICZ M., STAROSTA W. (2011), Asymmetry of paddling technique, its selected conditions and changeability in highly advanced kayakers, AWF, Poznań, IASK library – Vol. 35.
- RYNKIEWICZ T. (2003), Struktura zdolności motorycznych oraz jej globalne i lokalne przejawy, AWF, Poznań.
- RYNKIEWICZ T. (2009), Kajakarstwo klasyczne, monografia no. 60, Poznań.
- RYNKIEWICZ T., RYNKIEWICZ M. (2009), Kajakarstwo – trening dzieci i młodzieży, PZKaj, Warszawa.

- SAINBURG R. L. (2005), Handedness: Differential specializations for control of trajectory and position, *Exerc. Sport Sci., Rev.* 33, 4, pp. 206-213.
- SALMI J. A. (2003), Body composition assessment with segmental multifrequency bioimpedance method, *J Sports Sci Med*, 2 (Suppl. 3), pp. 1-30.
- SANCHIS-MOYSI J., DORADO C., VICENTE-RODRIGUEZ G., MILUTINOVIC L., GARCES G. L., CALBET J. A. L. (2004), Inter-arm asymmetry in bone mineral content and bone area in postmenopausal recreational tennis players, "Maturitas", 48(3), pp. 289-98.
- SŁAWIŃSKA T., ROŻEK K., IGNASIAK Z. (2006), Asymetria ciała w obrębie tułowia dzieci wczesnej specjalizacji sportowej, "Medycyna Sportowa", 2, pp. 97-100.
- STAROSTA W. (2008), Stronne zróżnicowanie techniki ćwiczeń zawodników rozmaitych dyscyplin sportu. Wyższa Szkoła Wychowania Fizycznego i Turystyki, Supraśl.
- WOLAŃSKI N. (1975), Rozwój biologiczny człowieka. PWN, Warszawa.

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Keywords: asymmetry, muscle mass, canoeing, sports training.

This work aims to investigate whether long-term canoeing causes asymmetry of muscle and fat distribution. It was assumed that long-term paddling would be reflected in the asymmetry of segmental body composition analysis. The research involved 40 competitors who train canoeing, among whom, 19 have the experience of 7 years minimum, and 21 of no longer than 3 years. The measurement of electrical bioimpedance was used as the research method, which allowed the authors to determine muscle mass and fat mass in the upper and lower limbs, and the torso. The asymmetry indicators were calculated and then the significance tests on differences between both groups were used. On the basis of the obtained results, it was discovered that statistically significant differences exist between the two groups regarding the asymmetry of muscle mass in the lower limbs. It was surprising that the newcomers revealed larger asymmetry. The asymmetry of fat tissue distribution in the lower limbs was bigger only in the advanced competitors, however, the differences were not statistically significant. On the basis of the obtained results, it was not possible to confirm the hypothesis that canoeing causes an increased level of muscle mass asymmetry.

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CZY WIOSŁOWANIE W KANADYJCE POWODUJE ASYMETRIĘ ROZKŁADU MASY MIĘŚNIOWEJ I TŁUSZCZU?

Słowa kluczowe: asymetria, masa mięśniowa, kajakarstwo, trening sportowy.

Celem pracy było sprawdzenie, czy wiosłowanie w kanadyjce powoduje asymetrię rozmieszczenia masy ciała. Założono, że długotrwałe nierównomierne obciążenie kończyn po prawej i lewej stronie ciała będzie dostrzegalne podczas analizy segmentowej składu ciała. Badaniom poddano 40 zawodników trenujących kajakarstwo, z tego 19 przez minimum 7 lat, oraz 21 nie dłużej niż 3 lata. Jako metodę badawczą wykorzystano pomiar

bioimpedancji elektrycznej, co pozwoliło na określenie masy mięśniowej i masy tłuszczu w obrębie kończyn górnych i dolnych oraz tułowia. Obliczono wskaźniki asymetrii, a następnie zastosowano testy istotności różnic pomiędzy obiema grupami. Na podstawie uzyskanych wyników stwierdzono istotną statystycznie różnicę w zakresie asymetrii masy mięśniowej kończyn dolnych. Zaskakujące był fakt, że większą asymetrią cechowali się początkujący zawodnicy. Jedynie w zakresie asymetrii rozmieszczenia tkanki tłuszczowej kończyn dolnych zaobserwowano większą asymetrię u zaawansowanych zawodników, jednak różnice nie były istotne statystycznie. Na podstawie uzyskanych wyników nie udało się potwierdzić hipotezy, że wiosłowanie w kanadyjkach powoduje zwiększony poziom asymetrii masy mięśniowej.