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An analysis of the correlation between kinesthetic differentiation capacity and the maximum force level in lower limbs

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abstract

Background Among specific coordination abilities, kinesthetic differentiation capacity of movement belongs to the most crucial factors fostering rational human behavior in the surrounding environment. The capacity is universal – indispensable in nearly all sports disciplines. One of the most important constituent elements of kinesthetic differentiation is the so-called "force sense," defined as differentiation of movement with respect to administering appropriate force. The authors of the study analyzed the correlation between the maximum force level in lower limbs and the accuracy of applying a targeted force value.

Material/Methods The study was conducted on 54 participants, students from the University School of Physical Education in Wrocław. To determine the maximum force (Fmax) and force sense in lower limbs, a specialist device was used, "the characterograph of muscle strength in limbs".

Results The mean force sense was 43.28 N in the participants' left lower limbs, and 58.33 N in the right limbs. The mean maximum force (Fmax) was higher in the right lower limb (897.17 N) than in the left one (769.94 N). The correlation coefficient between the variables of the maximum force level and the force sense in the left lower limb was 0.38. The same level of correlation was observed for the right lower limb (0.37).

Conclusions The positive correlation observed between the higher level of maximum force and kinesthetic differentiation of lower limbs in students from the University School of Physical Education in Wrocław implies that a training session appropriately planned to raise the maximum force level may positively influence the force sense value.

Key words kinesthetic differentiation, maximum force, force sense

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INTRODUCTION

The human capacity to move is conditioned by both management and control of the course of any movement. Gierat and Górska [1] are of the opinion that people who are about to make a particular movement, anticipate it, in their minds planning the movement on the basis of information received through the senses. The process involves a sensory–intellectual analysis of the situation and planning the course of action. When the movement is being executed, its course is compared to what was planned and further activity is modified upon receipt of feedback about the effectiveness of the executive system. This is a multi-layer complex neurophysiological process, whose quality depends on the efficiency and integration of the functions of the central and peripheral nervous systems with regard to movement coordination. This integration entails the following levels: the spinal cord, the brain stem, the cerebellum, the basal ganglia, the cerebral cortex. At the level of both central and peripheral nervous systems, it allows people to choose an appropriate strategy, trajectory or velocity of movement, which translates into higher level of movement coordination [2]. At the same time, according to a number of researchers, among specific coordination abilities, kinesthetic differentiation capacity of movement belongs to the most crucial factors fostering rational human behavior in the surrounding environment [3]. Some authors emphasize the need to develop and use this capacity to increase the effectiveness of each movement [4, 5]. The capacity is universal – indispensable in nearly all sports disciplines, but also essential in daily locomotive activities. Its high level promotes execution of economical movements, according to the rule: 'maximum effect with the least effort.' Differentiation of movement with regard to applying an appropriate force is defined as 'force sense' [6]. At the same time there are claims about the existence of a correlation between force sense and the so-called kinesthetic sense, a basis for movement management in sport and elsewhere. The correlation directly depends on the appropriate level of muscle strength, which conditions the correct posture, fitness and achievement of high sports results [7, 8, 9, 10, 11]. Many authors also observe a correlation between kinesthetic differentiation capacity and accuracy of movements with regard to physical capacity [12, 13, 14, 15, 16, 17]. Bearing this in mind, coupled with, the necessity, enforced by contemporary civilization, of rational stimulation and development of human coordination abilities in particular, the authors of this study decided to analyze the correlation between the maximum force level in lower limbs and the accuracy of applying a targeted force value.

MATERIAL AND METHODS

The study was conducted on 54 participants, students from the University School of Physical Education in Wrocław. To determine the maximum force (Fmax) and force sense of lower limbs a specialist device was used, 'the characterograph of muscle strength in limbs'. The device consists of a seat capable of linear movement, mechanisms measuring the moment of force of limb pressure, a set of measuring instruments (tensometric sensors and goniometers for measuring the range of motion in knee joints) and a recording-calculating system. During the experiment participants occupied the seat, with their back resting on a firm support. Lower limbs were positioned in designated places on bars of the lever mechanism. Goniometric sensors were attached to knee joints. The participants, by pressing the levers, transferred the pressure onto tensometric sensors. The signal stemming from the pressure was sent from the sensor to the computer via an amplifier and an AD/DA card. Data analysis was conducted with dedicated computer software. At the beginning of the study the participants generated the maximum force with their left and right lower limb separately. Subsequently, 50% value of maximum force (50%Fmax – the so-called model) was determined in one attempt (with the scale visible). Such a value was proposed since the participants considerably better deal with (are more accurate in) tasks where the replicated forces approach the maximum or the minimum (e.g. 85% or 25%). Then, to allow the participants to develop the ability to optimally apply a targeted force value, in each configuration there were ten attempts with the scale visible and hidden alternately, allowing the participants to use their kinesthetic memory. The experiment proper began with replicating 50%Fmax in five attempts relying on the participants' memory (with the scale hidden), for the right and the left lower limb separately. The force sense in lower limbs in participants was calculated on the basis of the difference between the mean value of 'the model' and the mean of three attempts of replicating 50% of the maximum force with the scale hidden. The material was analyzed with the help of commonly used descriptive statistics methods. The basic characteristics included calculating the means, standard deviations, coefficients of variation as well as the minimum and the maximum. All the calculations for this study were done in STATISTICA 10.0.

RESULTS

The results were presented as relative values of the analyzed parameters (Table 1). The mean force sense was 43.28 N in the participants' left lower limb, and 58.33 N in the right limb. The mean maximum force (Fmax) in the right lower limb was higher (897.17N) than the corresponding value in the left limb (769.94 N), but the difference is not statistically significant ($P = 0.8$). The highest maximum force value was 1308 N in the left lower limb and 1530 N in the right limb. The lowest maximum force values generated by participants were 294 N in the right lower limb and 216 N in the left lower limb respectively. The correlation coefficient between the variables of maximum force level and force sense of the left lower limb was 0.38. In the right lower limb the correlation was at the same level (0.37). The results achieved are not statistically significant ($p > 0.05$).

Table 1. Statistical analysis of parameters in the study

Variable	N	Mean	Standard deviation	Coefficient of variation	Minimum	Maximum	Range	Median	Lower quartile.	Upper quartile	Interquartile range	Skewness
Force sense L abs [N]	54	43.28	35.11	81.13	0.00	153.00	153.00	36.00	15.00	57.00	42.00	1.40
Force sense R abs [N]	54	58.33	57.15	97.98	3.00	243.00	240.00	40.50	15.00	87.00	72.00	1.67
Model F50% Left [N]	54	385.17	115.53	30.00	147.00	654.00	507.00	393.00	306.00	450.00	144.00	0.14
Model F50% Right [N]	54	448.39	161.76	36.07	108.00	765.00	657.00	414.00	339.00	588.00	249.00	0.24
Mean of 3 attempts F50% L [N]	54	365.56	107.19	29.32	120.00	594.00	474.00	360.00	318.00	423.00	105.00	-0.16
Mean of 3 attempts F50% P [N]	54	436.61	151.82	34.77	111.00	774.00	663.00	418.50	336.00	522.00	186.00	0.40
F max L [N]	54	769.94	230.33	29.92	294.00	1308.00	1014.00	786.00	612.00	900.00	288.00	0.14
F max R [N]	54	897.17	323.85	36.10	216.00	1530.00	1314.00	828.00	678.00	1179.00	501.00	0.24

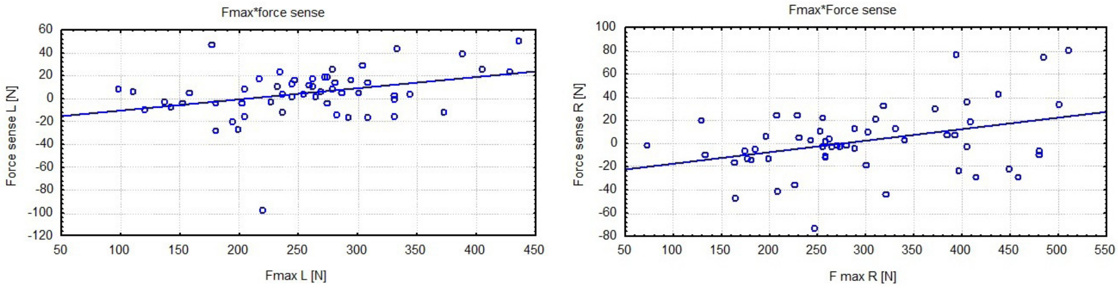

Fig. 1. Correlation between the maximum force level and force sense in the participants left (L) and right (P) lower limbs

DISCUSSION

According to Guilford [18] a correlation coefficient higher than 0.3 but lower than 0.5 signifies a moderate correlation. However, a positive correlation indicates that both parameters will increase or decrease at the same time. It may thus be inferred that an increase in the maximum force generated with the left and the right lower limb will cause an increase in the force sense of these limbs. Therefore, an increase, through appropriate training, of the maximum force level in a limb results in a higher level of kinesthetic differentiation of movements, which can lead to a higher and more effective level of movement management. This is also important in the context of an increased level of proprioception, which in effect signifies an improvement of human locomotive abilities. Recent studies offer proof that adaptation of muscle strength in lower limbs in persons aged 41-71 significantly improves the ability to balance one's body and as a result effectively prevents falls [19, 20]. Research also demonstrates that strength training has an important influence on neurological processes in the human organism [7, 9]. Yet, studies analyzing the direct dependence between kinesthetic differentiation and muscle strength are not conclusive, and researchers opinions vary in this respect [21]. Ljach and Starosta [22], who studied 88 pairs of twins, conclude that force sense is equally dependent on genetic and environmental factors. On the other hand, Szopa [23] claims that proprioceptive sense depends on genetic factors. Starosta [3], in a study devoted to the level of differentiation capacity of muscle strength in a group of 269 primary school pupils from Prešov, observed that the 'force sense' deteriorates and differentiation of the amplitude of movement improves with age. The author ascribes this phenomenon to the compensatory mechanism of various constituent parts of muscle and joint proprioceptors. Deterioration in differentiation capacity of force strength was also observed by Bajdziński and Kos [24] while conducting a study on a group of 113 tennis players. However, Starosta's test revealed an increase in the level of global movement coordination of the participants. The results made researchers speculate why the 'force sense' level decreases with age. Starosta [4] believes that it may be due to lack of early motor education of children which should develop the capacity in question, since it not only determines sports results, but it is also invaluable in daily life and subsequently in professional life. The author claims that athletes with impressive sports results manifest a high level of differentiation capacity of force strength, 'as employment of force sense is an element of effective sports techniques'. The study's results inspired the authors to conduct further analysis and a long-term experiment with the use of various methods of strength training.

CONCLUSIONS

The positive correlation observed between the higher level of maximum force and kinesthetic differentiation of lower limbs in students from the University School of Physical Education in Wrocław implies that a training session appropriately planned to raise the maximum force level may positively influence the force sense value.

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