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Sports Training

Do lower limb deficiencies interfere with the recruitment of the trunk and upper limb muscles of paracanoe athletes?

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Abstract - Aim: This study aimed to compare the recruitment of the anterior deltoid, pectoralis major, triceps (long head), and latissimus dorsi muscles during rowing, in paracanoe and canoe athletes. **Methods:** This is a cross-sectional study, with ethical approval, including a sample of five paraplegic athletes, four lower limb amputees, and four athletes without disabilities. Surface electromyography of the anterior deltoid, pectoralis major, triceps (long head), and latissimus dorsi muscles. The athletes rowed for three minutes in an ergometer kayak. The Root Mean Square (RMS) signal of the second minute of data collection, normalized by the RMS peak (% RMS), was considered for analysis. **Results:** The results of paraplegic athletes, amputees, and athletes without disabilities were similar, as follows; the anterior deltoid: 10.81 ± 3.1; 9.6 ± 3.13 and 9.92 ± 3.12 (p = 0.83), pectoralis major: 7.71 ± 0.66; 8.66 ± 0.66 and 8.53 ± 2.62 (p = 0.72), long head of the triceps: 8.41 ± 3.05; 4.79 ± 1.2 and 6.66 ± 1.01 (p = 0.08), and latissimus dorsi: 8.18 ± 1.97; 6.39 ± 2.64 and 6.95 ± 1.64 (p = 0.45). **Conclusion:** Paracanoe and canoe athletes present similar muscle recruitment of the upper limbs and trunk during rowing.

Keywords: electromyography, water sports, sports for persons with disabilities, amputation.

Introduction

Paracanoe is an aquatic sport that debuted at the Rio de Janeiro Paralympics in 2016. It is played by athletes with physical and motor disabilities of the lower limbs, distributed into classes inside the vessel according to their physical abilities[1]. The competitions are developed in 200-m races, with two possible vessels: the kayak, which debuted in the Brazilian games, or the Hawaiian canoe (va'a) which will debut in Japan[2].

Biomechanically, the kayak paddling gesture is predominantly performed by the upper limbs, however, the trunk and lower limbs assist in providing stabilization, generating muscle strength and power to be transferred to the upper limbs[3]. Thus, paracanoe athletes, who present limitations and deficiencies in the trunk and lower limbs, could present compensations for muscle recruitment and increased activation to develop the sporting gesture of the stroke.

Surface electromyography used to establish possible changes in muscle recruitment has been widely applied to compare the effectiveness of changes in the recruitment of motor units, and to characterize muscle activity in a given task[4]. The results of studies with electromyography show that canoeing athletes have great recruitment of shoulder muscles, such as the deltoid and latissimus dorsi, which are joint stabilizers and powerful torque generators[5], as well as the brachial and pectoralis major[6].

However, to date, no studies have focused on paracanoe athletes, which highlights a large gap in the literature and the need for further studies. In this sense, the objective of the current study was to compare the recruitment of muscles of the upper limbs and trunk during the execution of the stroke movement, in athletes with muscle power deficiencies in the lower limbs, athletes with limb deficiencies (lower limb amputations), and conventional canoeists without disabilities. It was hypothesized that, due to the need for compensations, especially in the trunk, differences in recruitment may occur of the main muscles of the stroke in the upper limbs and trunk, with greater recruitment and activation in athletes with physical dysfunctions.

Method

Type of study and ethical approval

This is a cross-sectional study, developed with Brazilian paracanoe and canoe athletes. The research was approved by the institution's Research and Ethics Committee (Opinion No. 2,491,352). The clubs were contacted, and the research procedures were explained before the clubs and athletes signed the consent form.

Participants and recruitment

The study was presented and explained at a meeting of directors and coaches, and to all athletes who participated in the Brazil Canoe and Paracanoe Cup, in the city of Curitiba - Paraná - Brazil in 2018. In total, 16 athletes and 26 parathletes participating in the Brazil Canoe and Paracanoe Cup 2018 were invited to participate in the study. The inclusion criteria were male, competing in the kayak vessel, and competing in the senior or paracanoe category. Parathletes who were unable to remain in the assessment position in the ergometer kayak were excluded.

For the calculation of the sample size was considered the values presented for athletes without disabilities in the article “A biomechanical assessment of ergometer task specificity in elite flatwater kayakers”[7], in the variable EMG activity - iEMG of TB, which presented the mean values of 179 and 239, and difference of 60. A confidence interval of 95%, an alpha level of 5%, and a test power of 90% were considered. That established a sample of 3 participants for each group as a minimum. Then the sample was established in 4 and 5 participants per group.

Participation was voluntary and five athletes with muscle power deficiency (low spinal cord injury), four with limb deficiency (lower limb amputees), and four athletes without physical disability agreed to participate in the study. Thus, the final sample of this study was composed of 13 canoe athletes linked to Brazilian sports clubs.

Collection location

The evaluation of athletes and parathletes was carried out in a specific tent for data collection, with an ambient temperature that ranged from 23˚C to 26˚C, similar to the real temperatures of training and competitions. The movements performed in the ergometer kayak simulated the reality of training and sports practice. As the data collection was carried out during the main national competition. Research participants were evaluated before their tests to avoid any harmful effects of fatigue. It is noteworthy that the climatic condition, the location of data collection, the time of the training season, and the periodization of training for the main national competition, as well as the collection in the competition environment, simulated the reality of canoeing athletes, which increases the relevance of the results in the application in sports practice.

Procedures

The athletes and parathletes were seated in the KayakPro® ergometer kayak comfortably and stably. In the case of spinal cord injured athletes, some adaptations were made to the seat, such as a backrest and/or lateral supports, for greater stability of the athlete[8]. The skin was cleaned and shaved to fix the electrodes for surface electromyography of the anterior deltoid, pectoralis major, triceps (long head), and latissimus dorsi muscles, according to the positioning rules proposed by Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscle (SENIAM) (Figure 1).

The collection of the electromyographic signal was performed employing an 8-channel electromyograph (model EMG SAS1000V8, EMG System®, BRA). The EMG signal was captured with four pre-amplified active electrodes and filtered in a bandpass filter between 25 and 450 Hz, with a sampling frequency of 2000 Hz. To control and exclude interferences in the electromyographic signals, the attempt set up for the collection was made of plastic material, all researchers, technicians, and those who needed to enter the attempt were instructed to enter without any electronic equipment and even so during signal collection only those indispensable for data collection remained in the space, also, both the computer and the electromyograph operated with battery, with no connection with the electrical network.

The Root Mean Square (RMS) of the amplitude of the EMG signal was calculated to determine the time of the event and define the average amplitude of the RMS concerning the task time for each muscle. The average values of the RMS were calculated for each muscle and normalized by the RMS peak to extract the percentage of recruitment/muscle contribution now of the stroke.

Parathletes and canoe athletes were instructed to row for 3 min. The first minute had an intensity and speed related to R1 (approximately 60-70 rpm and heart rate (HR) in the range of 55-65% of the maximum), the second minute an intensity and speed related to R3 (75-90 rpm and

Figure 1 - Parathlete positioned on the ergometer with electromyography signal capture electrodes and heart rate monitor, in the initial position of the sports gesture.

75-85% of maximum HR), and finally, the last-minute an intensity and speed related to R0 (40-60 rpm and < 60%). Heart rate was captured by the Polar® H9 heart rate sensor and monitored by the HRV4Training® application. The maximum heart rate was determined by the formula of Karvonen et al. 1957 [9].

To establish the results of muscle recruitment in the rowing movement, the RMS value of the second minute was considered, and the peak of the RMS of the second minute was used to normalize the data.

Statistical analysis

To compare the recruitment of the anterior deltoid, pectoralis major, triceps (long head), and latissimus dorsi muscles, between groups of athletes with spinal cord injury, amputations, and without dysfunction, the statistical analysis was performed using SPSS® 20.0 software. The Shapiro Wilk test was used, and analysis of variance (ANOVA), with the Bonferroni post-test, for comparison of the active muscles within the groups as well as in the comparison analysis between the groups. Significance was established at 5%.

Results

The canoe and paracanoe athletes evaluated in the present study were characterized as: with muscle power deficiency (N = 5), with limb deficiency (N = 4), and without physical deficiency (N = 4), all-male. The sample characterization data are shown in Table 1. A significant age difference was found between the athletes.

The deficiency in muscle power was due to spinal cord injury, with motor level impairments that affect the trunk and/or lower limb function. These impairments fall into classes KL1 or KL2 of the sport's functional classification, where KL1 represents lower trunk and lower limb involvement, and KL2 only lower limb involvement[2]. Limb deficiency, for the athletes evaluated in this study, meant amputation of one of the lower limbs, at the transfemoral level, knee disarticulation, or transtibial, with the contribution of only one lower limb to the moment of the stroke.

When analyzing the electromyographic recruitment of the pectoralis major, anterior deltoid, long head of the triceps, and latissimus dorsi muscles, both in the intra and between-group comparisons, the analysis of variance did not show any significant difference, indicating that there is a similarity in muscle activity between the different conditions and between the evaluated muscles (Table 2). In addition, the comparison of muscle recruitment within the same group did not demonstrate a significant difference. It was possible to observe, in all groups, that the anterior deltoid muscle was the most active, followed by the pectoralis major, latissimus dorsi, and, lastly, the triceps brachii, which can be considered as a trend for greater recruitment of the deltoid muscle in canoe and paracanoe athletes.

Discussion

The present study is the first to compare the muscle recruitment of the upper limbs and trunk, using electromyographic surface analysis, in paracanoe and canoe athletes. No differences were established between the groups and muscles evaluated, which may contribute to a better understanding of the adaptations resulting from injury or adapted sport, for the organization of future training and prevention and rehabilitation processes in sport.

The parathletes presented muscle power deficiency due to spinal cord injury or unilateral lower limb deficiency, which are commonly found in the context of Paralympic sport[10-13]. The parathletes also showed a higher age when compared to the canoe athletes without disabilities, which was expected since the parathletes, in general, begin participation in the sport later, after the injury, and after a long rehabilitation process. These data are confirmed in the study by Derman et al.[11], who reported that within the Paralympic scenario, the majority of the canoeing athletes in the Rio 2016 games, were over the age of 35 years[14].

The stroke movement analyzed in the present study requires the activation and control of large muscle groups, especially those of the upper limbs. For canoeing athletes without any disability, the main use of the anterior deltoid, pectoralis major, latissimus dorsi, and triceps brachii mus-

Table 1 - Characterization data for the evaluated athletes.

	Power deficiency	Limb deficiency	No disability	p
Age (years)	31 ± 1.87*	30.75 ± 10.30*	17.5 ± 2.88	0.012
Weight (kg)	69.4 ± 11.97	66 ± 9.30	73.25 ± 8.26	0.613
Height (cm)	178.6 ± 6.80	171.25 ± 9.05	177.5 ± 5	0.315
Practice time (years)	3.41 ± 1.29*	3.37 ± 1,79*	8.25 ± 2.98	0.010
Training/week	6 ± 1	5.75 ± 0.95	5.75 ± 0.95	0.905
Competitions/year	3.8 ± 0.44	3.75 ± 0.5	4 ± 0.81	0.822

Results are presented as mean and standard deviation. * Significant difference when compared to the group of athletes without disabilities, established by the analysis of variance with Bonferroni's post-test.

Table 2 - Analysis of muscle recruitment by surface electromyography, between the groups and muscles evaluated.

		Groups of athletes evaluated			p-value for comparison between groups
		Power deficiency	**Limb deficiency**	**No disability**	
Muscles	Pectoralis major	8.56 ± 0.66	7.71 ± 1.51	8.53 ± 2.62	0.721
	Anterior deltoid	10.81 ± 3.1	9.60 ± 3.13	9.92 ± 3.12	0.836
	Triceps (Long head)	8.41 ± 3.05	4.79 ± 1.2	6.66 ± 1.01	0.087
	Latissimus dorsi	8.18 ± 1.97	6.39 ± 2.64	6.95 ± 1.64	0.454
p-value comparison between muscles in the same group		0.313	0.061	0.201	

p-value of the comparison between the groups of athletes.
Values are expressed as a percentage of the peak of the RMS presented during the execution of the simulated stroke. p-value established by analysis of variance with Bonferroni post-test.

cles is indicated in the upper limbs, the recruitment of the multifidus muscles, erector spinae, oblique and rectus abdominis in the trunk[15], and the quadriceps muscle in the lower limbs[16]. Furthermore, the literature establishes the importance of the muscles of the trunk, pelvis, and lower limbs for transferring forces from the lower to the upper limbs in athletes without disabilities[17] and that the strength of the lower and upper limbs are equally important for the performance of speed kayaking[3].

However, in parathletes, the trunk and lower limbs may not act and assist in the movements and joint stabilization properly and could induce differences in the muscle recruitment of the upper limbs, as a way of compensating and adapting to the lesser transmission of forces that could come from the trunk and lower limbs. In this sense, it is known that elite and non-disabled athletes have a greater range of motion for the upper and lower limbs and torso during the stroke compared to athletes with disabilities[18], and consequently a higher stroke frequency of stroke to reach the desired speed[19], however in relation to muscle recruitment no previous studies are comparing these groups.

Contrary to the initial hypothesis of this study and reports in the literature[3,17], the results of this study did not establish differences in the recruitment of the anterior deltoid, pectoralis major, triceps (long head), and latissimus dorsi muscles, which characterizes the similar use between paracanoe and canoe athletes. The authors believe that neurological changes, such as plegia of the muscles of the lower limbs and the loss of part of the lower limb, could lead to greater recruitment of the muscles evaluated in paracanoe athletes, which was not found perhaps due to the high level of training imposed on national level athletes, such as those assessed in the present study.

As a limitation of this study, it should be noted that the results presented may have been influenced by the small size of our sample and that despite the explanations and invitations given to all 42 athletes who participated in the competition, only 13 volunteered to participate in the study. Possibly, many of the athletes believed that participation in research and data collection before the competitions could interfere with the results of their races and so they chose not to participate. In addition, there is a lack of studies in the area for adequate sample calculation. For future studies, a comparison of the frequency of stroke movements is suggested (how many stroke cycles at the same time), as well as analysis of the muscle strength of the upper limb and trunk muscles to favor a better understanding of the sports gesture and the possible differences between canoe athletes and paracanoe athletes.

Conclusion

Brazilian paracanoe athletes with muscle power deficiency (spinal cord injury) and lower limb deficiency (amputees) present similar muscle recruitment to canoe athletes without disabilities. The pectoralis major, anterior deltoid, triceps (long head), and latissimus dorsi muscles demonstrate similar electromyographic behavior in Brazilian kayak athletes and canoeists. Furthermore, there was no predominance of recruitment among the evaluated muscles.

Authors' contributions

All authors participated in the design of the study, contributed to data collection and data reduction/analysis, have read, and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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