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Effects of wheelchair sports practice on body composition of people with spinal cord injury

Efeitos da prática esportiva em cadeira de rodas na composição corporal de pessoas com lesão medular

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Abstract - The present study aimed to compare muscle mass and fat mass estimates between people with spinal cord injuries and their peers who participate in wheelchair sports. Thirty-six participants were divided into four groups: untrained paraplegics (UnP, N=7), wheelchair basketball players (WB, N=11), untrained quadriplegics (UnQ, N=8), and quadriplegic wheelchair rugby players (WR, N=10). Muscle mass and fat mass were assessed using anthropometric methods, measuring total muscle mass (MMTo, kg), leg muscle mass (MML, kg), trunk muscle mass (MMT, kg), arm muscle area (AMA, cm^2), upper limb fat mass (ULFM, %), lower limb fat mass (LLF, %), axial fat mass (MAx, %), appendicular fat mass (MApp, %), and total fat percentage (%F). Regarding muscle mass, the UnP group exhibited higher values compared to the WB group (AMA: 85.60±19.53 vs. 78.81±23.10; MML: 13.16±0.72 vs. 12.26±1.06; MMT: 25.06±1.67 vs. 22.97±2.47; MMTo: 52.86±10.85 vs. 46.01±3.38). For fat mass, the UnP group showed higher %F, ULFM, LLF, and MApp compared to the WB group (21.38±5.55 vs. 16.66±3.57; 28.43±10.33 vs. 18.97±6.57; 27.68±3.88 vs. 25.64±4.81; and 43.47±4.58 vs. 38.78±5.19, respectively) and lower (MAx 44.45±5.38 vs. 49.00±4.05). Among quadriplegic participants, the UnQ group had lower muscle mass values compared to the WR group (AMA: 49.91±13.78 vs. 51.58±12.97; MML: 12.12±0.98 vs. 12.73±1.35; MMT: 22.63±2.29 vs. 24.07±3.16; MMTo: 45.55±3.14 vs. 47.52±4.33). Regarding fat mass, the UnQ group had higher %F, ULFM, LLF, and MApp compared to the WR group (22.60±7.68 vs. 18.51±6.53; 25.38±11.73 vs. 21.90±8.92; 30.13±6.78 vs. 23.57±4.27; and 44.56±6.02 vs. 38.30±4.34, respectively) and lower MAx (44.62±6.33 vs. 49.92±2.91). In conclusion, participating in wheelchair sports can lead to beneficial changes in body composition among people with spinal cord injuries.

Key words: Disabled Persons; Para-Athletes; Sports for Persons with Disabilities; Anthropometry.

Resumo - *O presente estudo teve como objetivo comparar as estimativas de massa muscular e massa gorda entre indivíduos com lesão medular e seus pares que participam de esportes adaptados em cadeira de rodas. Trinta e seis participantes foram divididos em quatro grupos: paraplégicos não treinados (UnP, N = 7), jogadores de basquete em cadeira de rodas (WB, N = 11), quadriplégicos não treinados (UnQ, N = 8) e jogadores de rúgbi em cadeira de rodas (WR, N = 10). A massa muscular e a massa gorda foram avaliadas por meio de métodos antropométricos, considerando massa muscular total (MMTo, kg), massa muscular dos membros inferiores (MML, kg), massa muscular do tronco (MMT, kg), área muscular do braço (AMA, cm^2), massa gorda dos membros superiores (ULFM, %), massa gorda dos membros inferiores (LLF, %), massa gorda axial (MAx, %), massa gorda apendicular (MApp, %) e percentual total de gordura (%F). Em relação à massa muscular, o grupo UnP apresentou valores superiores ao grupo WB (AMA: 85,60 ± 19,53 vs. 78,81 ± 23,10; MML: 13,16 ± 0,72 vs. 12,26 ± 1,06; MMT: 25,06 ± 1,67 vs. 22,97 ± 2,47; MMTo: 52,86 ± 10,85 vs. 46,01 ± 3,38). Quanto à massa gorda, o grupo UnP apresentou maiores valores de %F, ULFM, LLF e MApp em comparação ao grupo WB (21,38 ± 5,55 vs. 16,66 ± 3,57; 28,43 ± 10,33 vs. 18,97 ± 6,57; 27,68 ± 3,88 vs. 25,64 ± 4,81; e 43,47 ± 4,58 vs. 38,78 ± 5,19, respectivamente) e menores valores de MAx (44,45 ± 5,38 vs. 49,00 ± 4,05). O grupo UnQ apresentou valores menores de massa muscular em comparação ao grupo WR AMA (49,91 ± 13,78 vs. 51,58 ± 12,97; MML: 12,12 ± 0,98 vs. 12,73 ± 1,35; MMT: 22,63 ± 2,29 vs. 24,07 ± 3,16; MMTo: 45,55 ± 3,14 vs. 47,52 ± 4,33). No que se refere à massa gorda, o grupo UnQ apresentou maiores valores de %F, ULFM, LLF e MApp em comparação ao grupo WR (22,60 ± 7,68 vs. 18,51 ± 6,53; 25,38 ± 11,73 vs. 21,90 ± 8,92; 30,13 ± 6,78 vs. 23,57 ± 4,27; e 44,56 ± 6,02 vs. 38,30 ± 4,34, respectivamente) e menor valor de MAx (44,62 ± 6,33 vs. 49,92 ± 2,91). Conclui-se que a prática de esportes adaptados em cadeira de rodas pode promover alterações benéficas na composição corporal de pessoas com lesão medular.*

Palavras-chave: *Pessoas com deficiência; Paratletas; Esportes para pessoas com deficiência; Antropometria.*

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INTRODUCTION

Traumatic spinal cord injury is a chronic condition caused by the death of afferent and efferent nerve cells, leading to multiple impairments in various aspects of human morphology and physiology[1]. Consequently, people with spinal cord injuries experience a decline in physical activity levels due to reduced mobility and the permanent use of wheelchairs for daily activities. This results in increased body fat accumulation and decreased muscle mass, contributing to adverse health conditions such as metabolic disorders and dyslipidemia[2], which, in turn, can lead to cardiovascular complications[3].

Engaging in physical exercise and participating in sports activities have proven to be crucial in mitigating these negative health effects, particularly in regulating body composition[4,5]. Wheelchair sports, such as rugby, basketball, and tennis, not only provide beneficial physiological stimuli but also enhance mobility by improving wheelchair maneuverability and propulsion skills, thereby offering functional advantages to participants[6].

Previous studies have demonstrated that various external stimuli, including clinical therapies and structured physical exercise programs, can induce significant and beneficial changes in body composition components[7-9]. However, few studies have specifically examined the impact of systematic participation in wheelchair sports on the body composition of people with traumatic spinal cord injuries. Another challenge lies in the techniques available for assessing body composition by region, as most rely on expensive and inaccessible equipment[10,11].

Moreover, laboratory-based body composition assessment methods have yet to become widely accessible, mainly due to the high cost and limited availability of sophisticated evaluation equipment. There is also a lack of validated, low-cost methods and instruments that could be used more frequently and effectively in rehabilitation and sports training settings. In contrast, anthropometric methods are considered a viable alternative for identifying regional body composition distribution[12,13].

Therefore, the objective of the present study was to compare muscle mass and fat mass estimates, obtained through anthropometric methods, between people with paraplegia and quadriplegia due to spinal cord injury and their counterparts who regularly participate in adapted wheelchair sports. By analyzing regional body composition differences, this study seeks to provide further insights into the potential benefits of sports participation for people with spinal cord injuries. The primary hypothesis is that athletes will exhibit more favorable muscle and fat distribution profiles than their untrained peers, characterized by higher muscle mass and lower fat accumulation. These differences are expected to reflect the physiological adaptations induced by regular physical activity, potentially contributing to improved functional capacity, metabolic health, and overall well-being in this population.

METHODS

Participants

This study included 36 participants, divided into four groups: untrained paraplegics (UnP, n=7), wheelchair basketball players (WB, n=11), untrained quadriplegics (UnQ, n=8), and quadriplegic wheelchair rugby players (WR, n=10). To recruit athletes from wheelchair sports, initial contact was made with regional and national federations via electronic invitations, followed by in-person visits. Data collection for the athlete groups was conducted at their respective training sites. For the untrained groups, participants were actively recruited from locations where people with spinal cord injuries reside or receive treatment. Personal invitations were extended individually, and data collection for these participants was carried out in a laboratory at the University of Pernambuco. All participants, both athletes and untrained people, were instructed to refrain from intense physical activity for 24 hours before data collection, as well as to avoid alcohol consumption while maintaining their usual diet. All research procedures adhered to ethical guidelines and were approved by the Research Ethics Committee of the University of Pernambuco (No. 1.678.117).

Assessment of clinical-demographic and sports practice variables

The demographic indicators of the subjects were collected to verify the athletes' training regimens, the types of physical impairment, and their functional classification. Regarding the training regimen, the time of practice of the modality, the weekly frequency of training, and the number of hours per day involved in the training were only verified. The data were recorded on paper forms and subsequently digitized in a spreadsheet (Microsoft Office 365, Excel, USA).

Morphological and body composition assessment

For morphological evaluation, the following anthropometric measurements were collected: body mass (kg), height (m), and skinfold thickness (mm). Data collection followed the recommendations of the *International Society for the Advancement of Kinanthropometry* (ISAK), with necessary adaptations[14]. To ensure methodological consistency, all measurements were conducted by the same trained evaluator. Body mass was measured using a digital scale (LD1050, Líder®). Participants were first weighed while seated in their wheelchair, followed by weighing the wheelchair alone. The participant's body mass was then obtained by subtracting the latter from the former. During the measurement, all subjects were instructed to remain as still as possible, and the reading was recorded once the scale's pointer stabilized. Height was measured with the participant in a supine position, using an inelastic measuring tape to determine the distance from the sole of the foot to the vertex of the head.

Skinfold thickness was assessed using a scientific skinfold caliper (Lange®, USA). To estimate overall adiposity, the sum of three skinfold measurements (triceps, abdomen, and thigh) was used in the following equation:

$$\%F = 8.997 + 0.24658 \times (triceps + abs + thigh) - 6.343 \times (gender) - 1.998 \times (race) \quad (1)$$

Where gender, 1 is considered for men and 0 for women, and about race, 1 is considered for afro-descendants and 0 for brown and white people[15]. To verify the muscular components, circumference data of the upper limbs were collected, in centimeters, using a metal anthropometric tape (Mabbis®, USA). The largest circumference at the level of the biceps was verified, with the evaluator positioned on the side of the volunteers. By using the arm circumference, corrected by the triceps skin fold, it was possible to calculate the muscular area of the arm, through the equation:

$$AA\left(cm^2\right)=\left[AC-\left(\pi\times TRT\right)\right]\times\left\{\left(\frac{2}{4}\right)\times\pi\right\} \quad (2)$$

Where AC is the arm circumference corrected to millimeters, π is 13.14, and TRT is the triceps skin fold in millimeters[14]. To verify muscle mass estimates by body region, the researcher used mathematical models developed and validated especially for people with paraplegia and quadriplegia[16] (Table 1).

Table 1. Mathematical models are proposed for the assessment of muscle mass in people with paraplegia and quadriplegia.

$\boldsymbol{MM\ legs(kg)}=\left(0.09\times\boldsymbol{body\ mass}\right)+6.1$	[3]
$\boldsymbol{MM\ trunk(kg)}=\left(0.21\times\boldsymbol{body\ mass}\right)+8.6$	[4]
$\boldsymbol{MM\ total(kg)}=\left(0.288\times\boldsymbol{body\ mass}\right)+26.3$	[5]

Statistical analysis

The assumptions of normality were assessed by analyzing the mean and standard deviation of the participants, as well as performing the Shapiro-Wilk test. Once these conditions were verified, an independent means comparison test (Independent T-Test) was conducted to compare body composition estimates between wheelchair sports practitioners and their untrained counterparts. Additionally, the effect size of the analyses was calculated following Cohen[17], recommendations, using G*Power software (Kiel, Germany), for comparisons that showed statistical significance. The analyses were performed using SPSS software, version 22 (IBM, USA), and GraphPad Prism, version 6.0 (Prism, USA). A significance level of 5% ($p\leq0.05$) was adopted for all statistical analyses.

RESULTS

A total of 36 people were evaluated, including 18 with paraplegia (spinal cord injury from T1 downward) and 18 with quadriplegia. Table 2 presents the demographic characteristics of all study participants.

Table 3 provides descriptive data on the body composition characteristics of the participants.

Regarding inferential analyses, Figure 1 illustrates the comparisons of muscle mass estimates among people with spinal cord injuries, categorized into paraplegics and quadriplegics. For people with paraplegia (Figure 1, panels A, C, E, and G), muscle mass estimates for the total body and specific regions were lower in sports practitioners than their untrained counterparts. However. only the total muscle mass estimate (Figure 1, panel G) demonstrated statistically significant differences between trained and untrained paraplegics. Conversely. in the quadriplegic group, all muscle mass estimates (Figure 1, panels B, D, F, and H) were higher among sports practitioners than their untrained counterparts.

Table 2. Clinical-demographic characteristics (mean ± standard deviation) and sports practice of the participants.

Variable (unit of measure)	UnP (n=7)	WB (n=11)[a]	UnQ (n=8)	WR (n=10)
Age (years)	37.14 ± 6.96	36.82 ± 9.00	37.88 ± 8.25	31.60 ±8.69
Weight (kg)	78.40 ± 7.95	68.45 ± 11.74	66.83 ± 10.90	73.68 ±15.03
Height (m)	165.61 ± 9.70	164.09 ± 12.82	172.31 ± 7.31	177.00 ± 2.16
BMI kg·(m2)	28.72 ± 3.47	25.41 ± 3.19	22.46 ± 2.93	23.53 ± 4.81
Injury site (C=cervical; T=thorax)	T1-L3	T11-L2	C4-C7	C4-T1
Injury time (months)	16.86 ± 14.16	11.18 ± 11.15	12.75 ± 5.23	11.45 ± 6.03
Prior time of injury (months)	20.29 ± 9.38	25.64 ± 18.36	25.13 ± 3.91	20.15 ± 9.61
Time of practice in mobility (months)	---	125.33 ± 116.43	---	51.80 ± 25.88
Training days per week (days)	---	4.47 ± 0.99	---	3.00 ± 0.00
Hours per day of training (hours)	---	3.03 ± 0.44	---	2.00 ± 0.00

Note. UnP = untrained paraplegics; WB = wheelchair basketball players; UnQ = untrained quadriplegics; WR = quadriplegic wheelchair rugby players; [a]5 subjects with poliomyelitis sequelae were included in the paraplegic group.

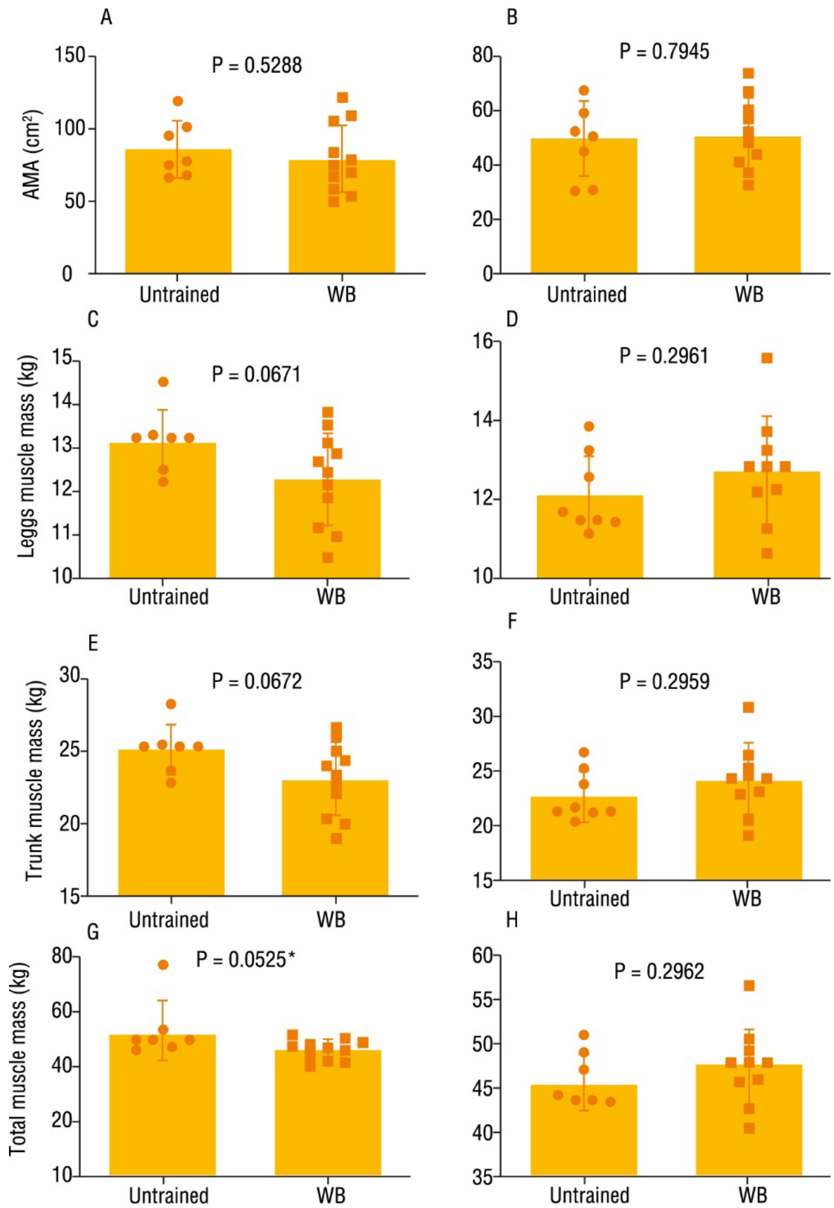

Figure 1. Comparisons between estimates of muscle mass of people with spinal cord injury. practitioners of sports modalities and untrained group; *The non-parametric similar statistical hypothesis test was used.

Table 3. Descriptive values of muscle mass and fat mass estimates for all participants.

ID	Muscle mass estimates				Adipose tissue estimates				
	AMA	MM Legs	MM Trunk	MM Total	%F	ULF	LLF	FAxial	FApp
Paraplegic group									
1	66.61	13.21	11.00	76.92	29.28	43.00	29.17	37.96	49.07
2	118.24	13.21	27.00	49.05	18.93	19.00	34.04	40.43	47.52
3	94.97	13.28	39.00	49.28	22.36	38.00	21.82	42.73	39.09
4	100.83	14.47	17.00	53.08	26.79	36.00	29.25	41.51	46.23
5	74.8	13.21	15.00	49.05	12.99	19.00	26.85	50.93	44.44
6	66.86	12.49	18.00	46.75	17.42	19.00	24.52	52.26	36.77
7	76.9	12.22	35.00	45.88	21.86	25.00	28.13	45.31	41.15
WB group									
8	77.13	13.12	24.98	48.76	16.95	19.64	26.7	47.81	40.26
9	74.8	13.75	26.45	50.78	14.96	16.00	22.58	50.81	35.48
10	67.34	13.48	25.82	49.92	15.94	15.00	28	48.51	41.55
11	83.12	12.67	23.93	47.32	13.31	13.00	30.61	46.17	41.67
12	108.43	11.86	22.04	44.73	16.93	24.00	24.55	50.3	38.92
13	120.41	12.13	22.67	45.6	18.44	27.00	16.37	51.46	32.16
14	50.38	11.14	20.36	42.43	13.48	18.00	32.71	40.19	49.53
15	103.62	12.85	24.35	47.9	26.08	33.00	26.86	45.94	42.33
16	69.68	10.96	19.94	41.85	17.18	15.00	28.49	49.32	38.67
17	53.76	10.51	18.89	40.41	13.5	17.00	19.04	54.84	31.99
18	58.19	12.39	23.29	46.44	16.44	11.00	26.09	53.68	34.04

ID	Muscle mass estimates				Adipose tissue estimates				
	AMA	MM Legs	MM Trunk	MM Total	%F	ULF	LLF	FAxial	FApp
Quadriplegic group									
19	67.09	13.22	25.21	49.08	31.75	41.00	27.13	42.51	43.72
20	52.86	11.46	21.1	43.44	14.00	11.00	28.41	51.14	40.91
21	59.16	13.84	26.66	51.07	21.61	27.00	28.28	43.44	42.96
22	44.58	11.50	21.20	43.58	35.38	39.00	34.29	36.19	52.86
23	50.67	11.68	21.62	44.16	22.11	17.00	33.33	47.86	43.02
24	31.03	11.14	20.36	42.43	13.23	15.00	34.65	39.60	49.50
25	30.57	11.50	21.20	43.58	21.37	18.00	38.51	40.99	49.69
26	63.31	12.58	23.72	47.04	21.37	35.00	16.42	55.22	33.83
WR group									
27	66.86	13.21	25.19	49.05	21.62	17.00	25.63	50.68	35.53
28	41.22	10.60	19.10	40.70	8.33	7.00	27.08	47.92	41.67
29	44.25	12.27	22.99	46.03	17.09	16.00	22.12	55.76	33.18
30	37.82	11.23	20.57	42.72	16.87	18.00	27.2	48.16	42.49
31	33.76	13.71	26.35	50.64	21.48	26.00	24.09	48.95	39.01
32	48.63	12.2	22.84	45.83	12.00	17.00	20.86	50.66	37.75
33	60.14	15.55	30.65	56.54	28.52	35.00	24.22	49.86	39.09
34	52.2	12.85	24.35	47.90	27.53	36.00	29.36	45.21	46.31
35	73.96	12.85	24.35	47.90	18.93	22.00	20.62	49	35.25
36	56.99	12.85	24.35	47.90	12.74	25.00	14.53	53.03	32.69

Note. ID (subject identification number); AMA (arm muscle area. cm^2); MM muscle mass. (kg); F (fat); ULF (upper limb fat. %); LLF (lower limb fat. %); FApp(appendicular fat. %).

Figure 2 shows the comparisons between estimates of fat mass for all subjects evaluated, paraplegic and quadriplegic. Regarding body fat estimates. in the paraplegic group (Figure 2, panels A, C, E, G, and I), lower values were observed in sports practitioners compared to the untrained group for total body fat percentage (Figure 2, panel A), upper limb fat mass (Figure 2, panel C), lower limb fat mass (Figure 2, panel E and appendicular fat mass (Figure 2, panel I). However, for axial fat mass estimation (Figure 2, panel G), the untrained group exhibited lower values than the practitioners.

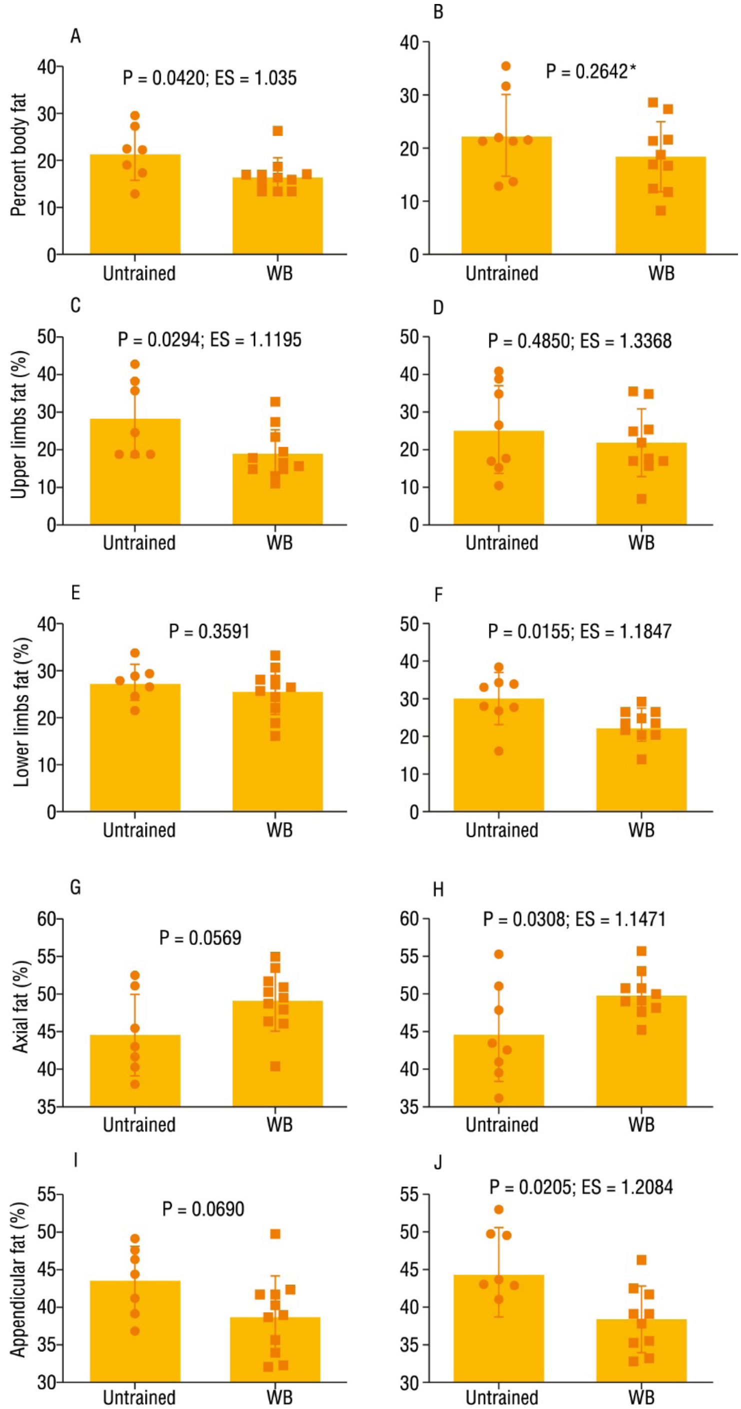

Figure 2. Comparisons between estimates of fat mass of people with spinal cord injury. practitioners of sports modalities and untrained group; *The non-parametric similar statistical hypothesis test was used.

Similarly, in the quadriplegic group (Figure 2, panels B, D, F, H, and J), body fat estimates were lower among sports practitioners compared to the untrained group for total body fat percentage (Figure 2, panel B), upper limb fat mass (Figure 2, panel D), lower limb fat mass (Figure 2, panel F), and appendicular fat mass (Figure 2, panel J). As observed in the paraplegic group. axial fat mass estimates (Figure 2, panel G) were lower in the untrained group compared to sports practitioners.

DISCUSSION

The present study aimed to compare general and regional body composition indicators in people with spinal cord injury, both practitioners and non-practitioners of systematized sports activities. Our findings suggest that athletes with SCI—whether paraplegic or quadriplegic—experience significant alterations in muscle mass and fat mass distribution, as assessed through anthropometric methods. These results align with previous studies highlighting the beneficial effects of sports participation in people with spinal cord injury[4,5,18]. However, it is important to note that this study focused specifically on WB and WR, limiting comparisons with other sports.

Several key findings warrant further discussion. Regarding muscle mass. quadriplegic athletes demonstrated higher values compared to their untrained counterparts—a trend not observed in the paraplegic groups. Prior research has already established the role of systematic physical training in muscle mass maintenance and hypertrophy[19-21]. However, to our knowledge, this is the first study to report such differences in total and regional lean mass among WR athletes.

WR is characterized by upper limb propulsion for locomotion, with athletes alternating between offensive and defensive maneuvers depending on ball possession[22]. This requires frequent short-duration, high-intensity bursts of effort involving multiple muscle groups for braking, maneuvering, and accelerating the wheelchair in various directions[23]. Additionally, WR involves intense physical interactions, such as ball disputes, defensive blocks, and tackling opponents[24]. These movements rely heavily on isometric muscle contractions, which, over time, may contribute to muscle mass maintenance and growth. Another critical aspect of WR is its aerobic demand, as the sport involves continuous, high-intensity play over extended periods[25]. This combination of factors may partially explain the higher total and regional muscle mass observed in quadriplegic rugby athletes.

Regarding fat mass. a general reduction was observed in nearly all regions among athletes, except for axial fat mass. This reduction is likely due to the combination of aerobic and anaerobic demands during training, which promote fat mobilization[26]. Aerobic metabolism, in particular, relies on oxygen uptake, transport, and utilization to generate energy[27]. Given that wheelchair sports predominantly engage the upper limbs (appendicular region), this likely stimulates muscle mass development while promoting fat mobilization in these areas. Conversely, movements involving the trunk (axial region) are relatively limited, which may contribute to higher fat retention in this area.

Interestingly, in the paraplegic groups, WB athletes exhibited reductions in both muscle and fat mass—except for axial fat—compared to their untrained counterparts. This suggests that the metabolic demands of basketball training may significantly influence fat mobilization and maintenance[28]. However, specific characteristics of the sport and its athletes may further explain these findings.

People with paraplegia, depending on their level of injury, may retain substantial upper-body mobility, sometimes comparable to or even exceeding that of able-bodied people[29]. When comparing people with spinal cord injury at different levels of impairment, functional mobility may be relatively similar. This could explain why no statistically significant differences in muscle mass were observed between trained and untrained paraplegics. despite a general trend of reduced values in trained athletes. A similar pattern was noted in body fat indicators.

WB is an intermittent sport, alternating between offensive and defensive plays, much like WR[30]. However, its tactical structure focuses on efficient court movement and positioning around the basket, requiring athletes to prioritize strategic mobility over direct physical engagement. This may subtly alter movement patterns, demanding greater overall displacement but fewer strength-based interactions compared to rugby.

One unexpected finding was the higher axial fat levels in WB athletes compared to untrained people. Although the precise cause remains unclear. the sport's movement patterns—predominantly involving seated propulsion with upper limb engagement—may contribute to fat retention in the trunk region. Additionally, some athletes in this study had a history of polio, a condition that causes flaccid paralysis[29]. Given the nature of this impairment, an overestimation of body fat in inactive regions, such as the trunk, is plausible. Despite these insights, some limitations must be acknowledged. The estimation of muscle mass relied solely on body mass[12], a variable subject to fluctuations due to hydration status and other behavioral factors. Future studies should consider incorporating hydration assessments and additional factors that may influence these measurements.

Another limitation is the small participants size across all comparison groups, which may reduce the statistical power of our analyses. Although acceptable effect sizes were observed, logistical constraints, accessibility to training and evaluation sites, and varying levels of athlete engagement limited overall participant recruitment. Additionally, the reliance on anthropometric methods for body composition assessment poses inherent limitations. While low-cost methodologies are necessary for rehabilitation and sports training periodization, future research should explore alternative assessment techniques to enhance measurement accuracy.

CONCLUSION

Systematized sports practice appears to facilitate positive adaptations in the body composition of people with spinal cord injury. Given the distinct characteristics of each sport, particularly WR and WB, body composition components may be influenced in different ways, with the level of injury playing a crucial role in determining the extent of muscle engagement. These variations can be effectively assessed using doubly indirect body composition measurement techniques, which are valuable for professionals working with this population, providing a practical means of monitoring training and physical conditioning progress. Ultimately, this study reinforces the potential of structured sports participation as a tool for rehabilitation and the enhancement of physical health in people with spinal cord injury.

Compliance with ethical standards

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee –University of Pernambuco and the protocol (no. 1.678.117) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: SFMO and MCC. Performed the experiments: SFMO and LIGLO. Analyzed the data: SFMO, JIVO, and MCC. Contributed reagents/materials/analysis tools: SFMO, LIGLO, and MCC. Wrote the paper: SFMO and JIVO.

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