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The Role of Water-Based Exercise on Vertical Ground Reaction Forces in Overweight Children: A Pilot Study

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Abstract: The aquatic environment represents an adequate and safe alternative for children with overweight to exercise. However, the magnitude of the vertical ground reaction force (Fz) during these exercises is unknown in this population. Therefore, our study aimed to compare the Fz during the stationary running exercise between the aquatic and land environments in children with overweight or obesity. The study is characterized as a cross-over study. Seven children, two with overweight and five with obesity (4 boys and 3 girls; 9.7 ± 0.8 years), performed two experimental sessions, one on land and another in the aquatic environment. In both conditions, each participant performed 15 repetitions of the stationary running exercise at three different cadences (60, 80, and 100 b min^{-1}) in a randomized order. Their apparent weight was reduced by 72.1 ± 10.4% on average at the xiphoid process depth. The peak Fz, impulse, and loading rate were lower in the aquatic environment than on land ($p < 0.001$). Peak Fz was also lower at 80 b min^{-1} compared to 100 b min^{-1} ($p = 0.005$) and loading rate was higher at 100 b min^{-1} compared to 80 b min^{-1} ($p = 0.003$) and 60 b min^{-1} ($p < 0.001$) in the aquatic environment, whereas impulse was significantly reduced ($p < 0.001$) with the increasing cadence in both environments. It can be concluded that the aquatic environment reduces all the Fz outcomes investigated during stationary running and that exercise intensity seems to influence all these outcomes in the aquatic environment.

Keywords: dynamometry; aquatic exercises; impact; apparent weight

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Citation: Gomes, M.B.; Andrade, L.S.; Nunes, G.N.; Weymar, M.K.; Schaun, G.Z.; Alberton, C.L. The Role of Water-Based Exercise on Vertical Ground Reaction Forces in Overweight Children: A Pilot Study. *Obesities* **2021**, *1*, 209–219. https://doi.org/10.3390/obesities1030019

Academic Editor: Carmine Finelli

Received: 4 November 2021
Accepted: 16 December 2021
Published: 20 December 2021

1. Introduction

Overweight and obesity can be defined as an abnormal or excessive fat accumulation that can be detrimental to health [1]. Indeed, The World Health Organization (WHO) recognizes obesity as a serious public health issue because of its role as a risk factor for a series of diseases, such as cardiovascular diseases [2], type 2 diabetes [3], musculoskeletal disorders [4], and even some types of cancer [5]. Among children and adolescents aged between 5 and 19 years, the global prevalence of overweight and obesity rose from just 4% in 1975 to almost 18% in 2016 [6]. Considering that many children with obesity remain in this condition until adulthood, and given the adverse health consequences of obesity throughout their lives, the normalization of body weight during childhood is becoming increasingly important [7].

Although genetics influence the risk of developing obesity [8], the treatment and control of this condition has mainly focused on modifiable factors, especially changes in health-related behaviors, such as the regular practice of physical activity and improvement of eating habits [6]. When it comes to exercise, however, children with obesity may be less likely to engage in physical exercise in general, as the increase in body mass index (BMI) is associated with an increased risk of injuries and pain-related problems for the lower limbs [9]. However, exercises performed in the aquatic environment could be an exciting alternative for children with overweight and obesity. This statement is supported by a study that indicated that children with overweight reported greater enjoyment and musculoskeletal comfort levels during water-based exercises, as well as lower ratings of perceived exertion values, than during a similar exercise on land [10].

Studies have also shown that apparent weight was reduced by approximately 70% when eutrophic adult individuals were immersed at the xiphoid process level [11,12]. The magnitude of reduction was even higher, of close to 81%, in adult women with obesity [13]. Consequently, this reduction in apparent weight results in a lower mechanical overload on the lower-limb joints during exercises performed in the water environment [14]. The reduction in vertical ground reaction force (Fz) during different modes of aquatic exercise, such as water walking, running, jumping, and water aerobic exercises, compared to the same modalities performed on land is well recognized in the literature [11,13,15–23]. However, we are not aware of any study so far that has compared Fz between the aquatic and dry-land environments in children, whether eutrophic or with overweight and obesity.

Among the aforementioned studies, recent findings by Alberton et al. [13] are noteworthy. The authors measured Fz during water aerobic exercises in adult women with grade 1 obesity and found a 60% reduction in the Fz peak (Fz_{peak}) during the stationary running exercise performed at a submaximal intensity in the aquatic compared to the land environment. Thus, it appears that the reduction in Fz_{peak} during exercise in the aquatic environment can be even more significant for individuals with obesity than for those with normal weight (40 to 47%) [24,25], possibly due to differences in body density [13]. Moreover, increasing the stationary running intensity in women with obesity from submaximal to maximal resulted in a 6 to 25% increase in Fz_{peak} in water, whereas the same intensity manipulation resulted in a more pronounced increase of 44 to 50% on land [13]. This suggests that water-based exercises allow individuals to reach higher energy expenditure without equivalent increases in Fz. However, this study only compared the effects of intensity manipulation between the aquatic and land environments on Fz_{peak}, but other Fz parameters such as the loading rate (LR) and impulse were not investigated.

Thus, considering the importance of identifying alternative modes of exercise that provide a safe environment for children with overweight and obesity to exercise, the aquatic environment represents a suitable alternative to be considered. Therefore, it is relevant to understand the behavior of Fz (Fz_{peak}, LR, and impulse) in the aquatic environment for this population, especially in light of the benefits that performing exercises in the aquatic environment may have on the musculoskeletal health of the lower limbs. Thus, the present study aimed to compare the Fz responses during the stationary running exercise performed at three different cadences, both in the aquatic and land environments in children with overweight and obesity. Our initial hypothesis was that lower values would be observed for all Fz results in the aquatic environment. Furthermore, differences were expected for different cadences during exercise in both environments.

2. Materials and Methods

2.1. Study Design

The study is characterized as a cross-over study.

2.2. Participants

Our sample was composed of children with overweight or obesity who voluntarily took part in the study and were recruited through notes published on different social media platforms. The eligibility criteria adopted were: being between 9 and 12 years old, presenting overweight or obesity according to WHO's BMI for age values [26] being familiarized with the aquatic environment, and not having any osteoarticular limitations to exercise. The age range adopted in the present study was established in accordance with the depth of the pool available, so that the exercises in the aquatic environment could be performed safely and adequately. All participants and his or her legal guardian were fully informed about the study procedures and then signed consent and assent forms, respectively. The study was approved by the Local Ethics Research Committee (registration number: 17355219.0.0000.5313). The sample size was calculated using the G*Power 3.1 software (Kiel University, Kiel, Germany), adopting a 5% significance level and 99% power. Specifically, a 2.333 effect size f was adopted for the Fz_{peak} outcome between environments, based on data from Alberton et al. [13], whereas a 0.8365 and 1.3078 effect size f was adopted for the impulse and LR outcomes, respectively, based on data from Nunes et al. [21].

2.3. Experimental Procedures

The experimental procedures for the Fz data assessment were carried out in two experimental sessions. The first corresponded to the protocol performed in the land environment and the second in the aquatic environment, with a minimum of 24 h between them. The randomization of protocols between environments was not performed due to logistics reasons. The body weight and height were measured at the first session using a digital scale with a stadiometer (WELMY, Santa Bárbara d'Oeste—São Paulo, Brazil) and waist circumference using a tape measure (CESCORF, Porto Alegre, Brazil). From the body weight and height data, the BMI of each child was calculated and classified according to the age-related WHO's BMI curves (5–19 years) [26].

In both experimental sessions, the participants were initially positioned bare foot on the force platform (EMGSystem, São José dos Campos, Brazil), with their upper limbs extended and relaxed along their body to measure body weight on land or apparent weight in the aquatic environment, while immersed to the xiphoid process. Participants were then familiarized with the stationary running exercise at the different cadences assessed during protocols. Participants received instructions on the proper range of motion and how to control the rhythm of movement according to the selected cadence, reproduced using the Metronome app version 1.8.0 (Gismart, London, UK) in both environments.

The stationary running exercise was selected for the present study because it is commonly used in exercise sessions in the aquatic environment, and its Fz response has been investigated previously in adult individuals in a variety of contexts, providing a great means of comparison for the present data [10,11,13,17,19,24,25,27]. This exercise is characterized by unipodal support and a flight phase. Specifically, during the first phase of the exercise, the participant flexes his or her right hip and knee up to 90°, starting the flight phase. The right hip and knee are extended during the following phase, whereas the ankle is kept at a neutral position until the support phase begins again. Each phase corresponds to a metronome beat, according to the intended cadence, and each of the lower limbs performs the movement in an alternated fashion (i.e., when the right lower limb is in the support phase, the left lower limb is in the flight phase). The upper limbs perform a slight flexion and extension movement at the shoulder joint to provide balance and support, while the elbow joints are kept flexed at approximately 90°. In both environments, the experimental protocol consisted of the stationary running exercise performed at three pre-specified cadences (60 b min^{-1}, 80 b min^{-1}, and 100 b min^{-1}). A simple drawing randomly determined the cadences' order. Each participant performed fifteen stationary running repetitions in each cadence, with a 3 min rest between the repetitions to avoid acute fatigue that could influence the evaluated kinetic parameters [28]. The land protocol was carried out in a room with controlled room temperature between 22 and 26 °C and participants wearing personal sneakers. The aquatic environment protocol was performed in a swimming pool with the immersion depth kept at the xiphoid process and a water temperature between 30 and 31 °C, with the participants barefoot.

In order to assess Fz, an underwater vertical force platform (EMGSystem, São José dos Campos, Brazil) with a 200 kgf capacity was used. Participants were positioned on the platform so that only the right lower limb was supported to measure Fz. For this purpose, the force platform was positioned inside a larger wooden platform, which allowed the participant's lower left limb to perform the support phase at the same level as the contralateral leg during the flight phase. Data were acquired using a 1000 Hz sampling frequency and subsequently transmitted to a computer using the EMGLab V1.1 software (EMG Lab, Curitiba, Brazil).

The Fz signal was exported for analysis on the SAD32 software (Laboratory of Mechanical Measurements, Federal University of Rio Grande do Sul; Porto Alegre, Brazil). A 4th order Butterworth low-pass filter at a cutoff frequency of 10 Hz was applied to the signal, and the Fz_{peak}, impulse, and LR values during the support phase of all 15 repetitions were determined for each participant in each environment and cadence. The average of the 10 central repetitions, which were considered valid, was included in the analysis. The Fz_{peak} value was identified through the highest Fz value obtained during the support phase, expressed in N. The impulse values were analyzed using the force–time integral of the area of the curve corresponding to the contact time during the support phase, expressed in N s. Finally, the LR was analyzed based on the first derivative of force over time (N s^{-1}), considering the window of 10–90% of the initial contact to the first peak in the Fz signal. For the analysis, Fz_{peak}, impulse, and LR data were expressed relative to the total body weight obtained in the land condition (BW) and expressed in units of BW, N s BW^{-1}, and $BW.s^{-1}$, respectively. In addition, the percentage of reduction in apparent weight was determined from the relationship between BW and apparent weight during immersion at the xiphoid process, measured in N in both environments and expressed as a percent value (%).

2.4. Statistical Analysis

Data are presented as mean and standard deviation, absolute and relative frequency. For the comparison between environments (aquatic and land) and cadences (60, 80, and 100 b min^{-1}), Generalized Estimating Equations (GEE) with Bonferroni post hoc tests were used. In addition, Cohen's d effect size was calculated from the mean outcome values between the two environments and classified as small (0.2 to 0.5), moderate (0.5 to 0.8), or large (0.8 or greater) [29]. All tests were performed on the SPSS software version 20.0 (IBM Corporation, Armonk, NY, USA), and a significance level of $\alpha = 0.05$ was adopted.

3. Results

Seven children with overweight or obesity volunteered to participate in the present study. The characteristics of the study participants are shown in Table 1. All participants completed the sessions, and no adverse effects or safety concerns were observed during the exercise protocols. The average reduction in apparent weight at the xiphoid process level was 72.1 ± 10.4%.

Table 1. Characteristics of the study participants.

Characteristics	(*n* = 7)
Sex	
Girls, *n* (%)	3 (42.9%)
Boys, *n* (%)	4 (57.1%)
Age	
9 years-old, *n* (%)	3 (42.9%)
10 years-old, *n* (%)	3 (42.9%)
11 years-old, *n* (%)	1 (14.3%)
Height, cm, mean (SD)	152.57 (6.92)
Body weight, kg, mean (SD)	64.22 (13.05)
Waist circumference, cm, mean (SD)	84.71 (9.81)
BMI, kg m^{-2}, mean (SD)	27.41 (4.22)
z-score, BMI, kg m^{-2}	
Between 2 and 3, *n* (%)	2 (28.6%)
Above 3, *n* (%)	5 (71.4%)

SD = standard deviation; BMI = body mass index.

Table 2 presents the descriptive analysis of the outcomes (Fz_{peak}, impulse, and LR) in both environments during the performance of the stationary running exercise, at the three investigated cadences. The between-environment effect size of each outcome and its corresponding 95% confidence interval are also presented, whereas the individual values for the aforementioned outcomes are shown in Figure 1.

Fz_{peak} showed a significant environment*cadence interaction ($p = 0.024$). Specifically, Fz_{peak} was lower in the aquatic environment than on land in all cadences investigated ($p < 0.001$). In addition, the Fz_{peak} was also found to be lower at 80 b min^{-1} compared to 100 b min^{-1} ($p = 0.005$) in the aquatic environment, but at 60 b min^{-1} it was not different from the other cadences. No differences in Fz_{peak} were observed between cadences in the land environment. Impulse also showed a significant environment*cadence interaction ($p < 0.001$). The post hoc test for each main effect further confirmed the differences between environments and cadences; however, the magnitude of the difference between cadences was greater in the land environment. This is represented in Table 2. The environment effect showed that the impulse was lower in the aquatic environment compared to land in all of the cadences investigated ($p < 0.001$), which was accompanied by a reduction in impulse values in both the environments as cadence was increased (water: $p \leq 0.02$; land: $p < 0.001$).

Table 2. Descriptive analysis of the peak vertical ground reaction force (Fz_{peak}), impulse and loading rate (LR) in the aquatic and dry-land environments during the performance of the stationary running exercise at three different cadences (60, 80 and 100 b min^{-1}) ($n = 7$).

Outcome	Cadence	Aquatic Environment Mean (SD)	Dry-Land Environment Mean (SD)	% Reduction Mean (SD)	*d* (95% CI)
Fz_{peak} (BW)	60 b min^{-1}	0.82 (0.25) [ab]	2.09 (0.32) *[a]	60.08 (13.51)	4.08 (2.24–5.92)
	80 b min^{-1}	0.81 (0.18) [a]	2.14 (0.28) *[a]	62.19 (6.17)	5.21 (3.02–7.41)
	100 b min^{-1}	0.95 (0.22) [b]	2.08 (0.18) *[a]	54.33 (10.23)	5.19 (3.00–7.38)
Impulse (N s BW^{-1})	60 b min^{-1}	0.25 (0.10) [a]	1.03 (0.08) *[a]	75.73 (9.69)	7.95 (4.82–11.07)
	80 b min^{-1}	0.20 (0.07) [b]	0.80 (0.10) *[b]	75.22 (6.65)	6.41 (3.82–9.01)
	100 b min^{-1}	0.18 (0.07) [c]	0.70 (0.05) *[c]	74.05 (9.99)	7.89 (4.78–10.99)
LR ($BW.s^{-1}$)	60 b min^{-1}	5.04 (1.95) [a]	15.50 (6.66) *[a]	65.87 (12.86)	1.97 (0.69–3.24)
	80 b min^{-1}	6.29 (3.10) [a]	15.68 (5.05) *[a]	59.16 (16.73)	2.07 (0.77–3.37)
	100 b min^{-1}	7.79 (3.05) [b]	15.85 (6.06) *[a]	46.06 (26.06)	1.55 (0.36–2.75)

SD = standard deviation; 95% CI = 95% confidence interval; * significant difference between environments; different letters indicate significant differences between cadences (a < b < c).

As for the LR, a significant environment*cadence interaction was also observed ($p = 0.019$), indicating that the LR was lower in the aquatic environment than on land, regardless of the cadence investigated ($p \leq 0.001$). In addition, LR was higher at 100 b min^{-1} compared to 80 b min^{-1} ($p = 0.003$) and 60 b min^{-1} ($p < 0.001$) in the aquatic environment, but no difference was observed between 60 and 80 b min^{-1}. No differences in LR were observed between cadences on the land environment.

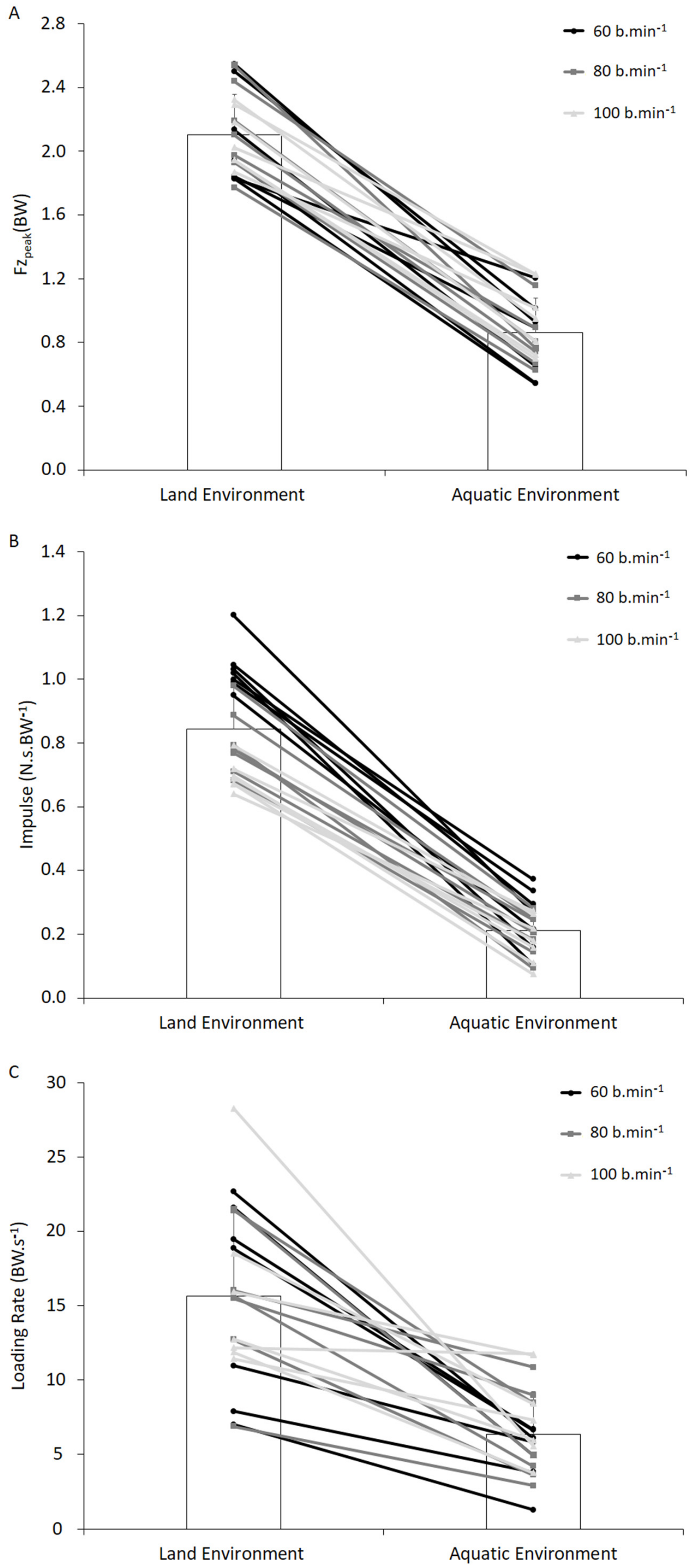

Figure 1. Mean (bars) and individual (lines) vertical ground reaction force (**A**), impulse (**B**) e loading rate (**C**) values in the aquatic and land environments during the performance of the stationary running exercise in three different cadences (60, 80 and 100 b min^{-1}). Note: Bars correspond only to the "environment" main effect representing the mean value for all cadences investigated in each environment.

4. Discussion

The aim of the present study was to compare the responses of the selected Fz parameters during the stationary running exercise performed at different cadences in the aquatic and land environments by children with overweight and obesity. In this regard, the main findings of the present investigation were that both Fz_{peak}, impulse, and LR were lower in the aquatic environment than on land. We also demonstrated that an increase in cadence resulted in a significant increase in Fz_{peak} and LR in the aquatic environment, which was not evidenced on land. Conversely, increasing cadence resulted in a reduction in impulse in both environments.

Apparent weight was reduced by 72% in the present population when immersed at the xiphoid process depth. Such a reduction in apparent weight may confer an advantage to children with obesity exercising in the aquatic environment because it relieves the overload imposed on the lower limb joints of these individuals, favoring the performance of exercises in this environment. This magnitude is in accordance with previous studies, which observed a 69 to 71% reduction in the apparent weight in eutrophic young adults immersed at the same level [11,12,24]. On the other hand, recent studies have shown even greater reductions of 75 to 81% in adult women with obesity [13], as well as in postmenopausal [30] and older adult women [31]. Differences in the aging process and body composition (muscle mass, fat mass, and bone density) could explain such differences in the magnitude of reduction between the aforementioned studies [32].

As for the difference observed between the environments during the performance of the stationary running exercise, we observed a 54–62% reduction in Fz_{peak}, 74–76% reduction in impulse, and 46–66% reduction in the LR in the aquatic environment for the three cadences investigated. The magnitude of these reductions is further reinforced by the large effect sizes observed between the environments in all variables and cadences (Fz_{peak} = 4.08 to 5.21, impulse = 6.41 to 7.95, LR = 1.55 to 2.07). These findings corroborate those of other studies that also observed substantial reductions in the Fz_{peak} when both environments were compared [11,13,17,19,24,25]. Alberton et al. [13] found reductions in the order of 60 to 67% in Fz_{peak} at 80 b min^{-1}, 100 b min^{-1}, and maximal effort in women with obesity, but no data is available on impulse or LR. In eutrophic young adults, the magnitude of reduction in Fz_{peak} during the stationary running exercise is typically somewhere between 40–58% at different submaximal intensities [11,17,24,25], whereas the impulse and LR were found to be 67.5–68.6% [11,24] and 20.6–38.6% [17] lower in the aquatic environment, respectively.

The reductions mentioned above are thought to occur as a result of the physical properties of water. Specifically, the buoyant force assists the submerged body when floating, leading to a reduction in apparent weight and a lower acceleration in the body's vertical displacement when the exercise is performed. This reduction seems to be even greater in individuals with overweight and obesity, possibly because of differences in body density. Therefore, the aquatic environment can be an interesting alternative for those in need of minimizing Fz when exercising, such as for children with overweight. For example, children performing the stationary running exercise on land would present a Fz_{peak} load greater than 2× his or her body weight. On the other hand, performing the same exercise in the water environment would result in a much lower Fz_{peak} load, close to 1× his or her body weight, representing a much lower risk for developing musculoskeletal injuries [33].

Regarding the effect of cadence on the performance of the stationary running exercise, an increase in Fz_{peak} was observed in the aquatic environment from 80 to 100 b min^{-1}, while no difference was found between 60 b min^{-1} and the other cadences (mean values ranging between 0.8–1.0 BW). These findings partially agree with previous studies that showed an increased Fz_{peak} as submaximal cadence increased for different water-based stationary exercises [11,13,19,24,30,34]. This increase in Fz_{peak} is likely related to the fact that as cadence increases, individuals need to apply a greater propulsive force to adequately overcome water resistance and promote the vertical propulsion of their bodies.

It is essential to highlight that all submaximal cadences employed in the studies above were equal to or greater than 80 b min^{-1}, resulting in Fz_{peak} magnitudes of 0.9 to 1.1 BW in eutrophic young adults [11,17,24,34] and 0.5 to 0.8 BW in individuals typically characterized by changes in body composition, such as adult women with obesity [13], postmenopausal women [30], older women [31] and those with type 2 diabetes [19]. As we were investigating children, we chose to include a lower initial cadence (i.e., 60 b min^{-1}); however, we observed that this exercise intensity seemed uncomfortable to the participants during the experimental sessions due to its slow pace. Accordingly, we observed a higher variability for Fz_{peak} at this specific cadence in the aquatic environment (coefficient of variation = 31% vs. 22–23%).

Nevertheless, no significant differences were observed for the Fz_{peak} between the same three cadences in the land environment (mean values corresponding to 2.1 BW). These findings are in disagreement with those in adult individuals, in which an increase in Fz_{peak} was observed with an increase in cadence at submaximal cadences [11,13,17,19,24]. It is noteworthy, however, that the Fz_{peak} magnitudes during the performance of the stationary running exercise ranged from 1.2 to 2.1 BW at different submaximal cadences in adult individuals (e.g., eutrophic young adults, young adults with obesity, individuals with type 2 diabetes). In contrast, the Fz_{peak} magnitude in our participants at the lowest cadence was comparable to the highest cadences in the aforementioned studies. This difference can be attributed to the different populations investigated and their different level of familiarity with this type of exercise performance, as this is the first study to assess this parameter in children with overweight.

Our findings also demonstrated that there was a significant reduction in impulse for both environments investigated with increasing cadence, which is in agreement with previously reported data in the literature [11,24,31]. The impulse depends on the force that is applied during the support phase. Accordingly, even though Fz_{peak} increased as cadence increased, the corresponding reduction in contact time during the support phase likely exerted a more substantial influence on this outcome. The behavior of the LR in response to the increase in exercise cadence observed by us is also in agreement with previous data in the literature, which showed an increase in the LR as cadence increased [17]. It is noteworthy, however, that in the present study, the magnitude of LR between 60 and 100 b min^{-1} was lower in the aquatic environment (5.04–7.79 BW.s^{-1}) and higher on land (15.50–15.85 BW.s^{-1}) compared to those verified in the study mentioned earlier, which analyzed cadences from 90 to 130 b min^{-1} in eutrophic young adults (water: 5.38–9.15 BW.s^{-1}; land: 8.76–11.52 BW.s^{-1}). These findings reinforce the role of minimizing the impact for children with overweight and obesity during the practice of exercises in the aquatic environment, since the higher the LR, the faster the body structures must adapt to a certain magnitude of force. On the other hand, individuals exposed to a greater force have a shorter time to adapt to this force as cadence is increased, as is the case for land-based exercises. As such, the aquatic environment can and should be recommended as a safe exercise paradigm for children with overweight, which allows them to exercise at different intensities and enables more significant energy expenditure during practice without exaggerated Fz_{peak} and LR responses.

We recognize that the absence of randomization between the environments might be a limitation; however, we could not perform randomization in this regard for logistic reasons. The absence of a separate session for participants' familiarization could also be mentioned as a potential limitation. The novelty of the task and the familiarization performed on the same day may have contributed to some of the variability observed in Fz. Additionally, the largest sample size requirement was observed for the impulse outcome, indicating that 8 participants were necessary. Data collection related to the seven participants reported in the present investigation was carried out between November and December 2019. However, due to the recommendations of social isolation resulting from the COVID-19 pandemic, we were required to discontinue data collection, which did not allow us to reach the calculated sample size of eight participants. Even though we could not to achieve the calculated sample size for the intended analyses, we were still able to demonstrate that all outcomes investigated were reduced in the aquatic environment compared to land. Moreover, we included both children with overweight and obesity in our sample, and future studies could aim to compare Fz responses between individuals with different levels of obesity and between more or less playful activities.

5. Conclusions

Our results evidenced that Fz_{peak}, impulse, and LR were lower in the aquatic environment than on land during the performance of the stationary running exercise in children with overweight and obesity. Furthermore, the magnitude of the investigated outcomes seemed to be influenced by the cadence in which the exercises were performed in the aquatic environment, whereas the impulse was reduced with an increase in cadence in both environments. These findings are relevant for the pediatric population with overweight and obesity, as they may benefit from exercising in the aquatic environment, where they encounter a lower burden on the lower limbs due to the reduction in apparent weight and, consequently, lower impact on their lower-limb joints when compared to exercising on land. Moreover, based on the results of the different cadences investigated, it is possible to suggest that even with an increase in intensity (i.e., increase in cadence), which is a key factor to increase exercise-related energy expenditure, Fz_{peak}, impulse, and LR were still considerably lower in the aquatic environment than in the highest cadences in the land environment. Consequently, the aquatic environment can be suggested as an alternative for children with overweight and obesity to exercise at greater intensities while also remaining safe from an osteoarticular perspective.

Author Contributions: Conceptualization, M.B.G. and C.L.A.; methodology, M.B.G., L.S.A., G.Z.S. and C.L.A.; formal analysis, M.B.G., L.S.A. and G.N.N.; data curation, M.B.G., L.S.A., G.N.N. and M.K.W.; writing—original draft preparation, M.B.G., L.S.A. and G.Z.S.; writing—review and editing, G.N.N., M.K.W. and C.L.A.; visualization, M.B.G.; supervision, L.S.A.; project administration, C.L.A. All authors have read and agreed to the published version of the manuscript.

Funding: Luana Siqueira Andrade is financed by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (CAPES)-Finance Code 001. Gustavo Zaccaria Schaun is supported by Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (FAPERGS). Cristine Lima Alberton is supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico – Brasil (CNPq)–number 431288/2018-6.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Research Ethics Committee of the School of Physical Education of the Federal University of Pelotas (CAAE: 17355219.0.0000.5313).

Informed Consent Statement: All participants and his or her legal guardian were fully informed about the study procedures and then signed consent and assent forms, respectively.

Acknowledgments: The authors thank the participants for their contribution to this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bosello, O.; Donataccio, M.P.; Cuzzolaro, M. Obesity or obesities? Controversies on the association between body mass index and premature mortality. *Eat. Weight Disord.-Stud. Anorex. Bulim. Obes.* **2016**, *21*, 165–174. [CrossRef] [PubMed]
2. Koliaki, C.; Liatis, S.; Kokkinos, A. Obesity and cardiovascular disease: Revisiting an old relationship. *Metabolism* **2019**, *92*, 98–107. [CrossRef] [PubMed]
3. Garber, A.J. Obesity and type 2 diabetes: Which patients are at risk? *Diabetes Obes. Metab.* **2012**, *14*, 399–408. [CrossRef] [PubMed]
4. Anandacoomarasamy, A.; Caterson, I.; Sambrook, P.; Fransen, M.; March, L. The impact of obesity on the musculoskeletal system. *Int. J. Obes.* **2008**, *32*, 211–222. [CrossRef]
5. Avgerinos, K.I.; Spyrou, N.; Mantzoros, C.S.; Dalamaga, M. Obesity and cancer risk: Emerging biological mechanisms and perspectives. *Metabolism* **2019**, *92*, 121–135. [CrossRef] [PubMed]
6. World Health Organization (WHO). Obesity. 2021. Available online: https://www.who.int/health-topics/obesity (accessed on 9 October 2021).
7. Weihrauch-Blüher, S.; Wiegand, S. Risk Factors and Implications of Childhood Obesity. *Curr. Obes. Rep.* **2018**, *7*, 254–259. [CrossRef]
8. Goodarzi, M.O. Genetics of obesity: What genetic association studies have taught us about the biology of obesity and its complications. *Lancet Diabetes Endocrinol.* **2018**, *6*, 223–236. [CrossRef]
9. Adams, A.L.; Kessler, J.I.; Deramerian, K.; Smith, N.; Black, M.H.; Porter, A.H.; Jacobsen, S.J.; Koebnick, C. Associations between childhood obesity and upper and lower extremity injuries. *Inj. Prev.* **2013**, *19*, 191–197. [CrossRef]
10. Yaghoubi, M.; Fink, P.W.; Page, W.H.; Heydari, A.; Shultz, S.P. Kinematic Comparison of Aquatic- and Land-Based Stationary Exercises in Overweight and Normal Weight Children. *Pediatri. Exerc. Sci.* **2019**, *31*, 314–321. [CrossRef]
11. Alberton, C.L.; Tartaruga, M.P.; Pinto, S.S.; Cadore, E.L.; Antunes, A.H.; Finatto, P.; Kruel, L.F. Vertical Ground Reaction Force during Water Exercises Performed at Different Intensities. *Int. J. Sports Med.* **2013**, *34*, 881–887. [CrossRef]
12. Harrison, R.; Hillman, M.; Bulstrode, S. Loading of the Lower Limb when Walking Partially Immersed: Implications for Clinical Practice. *Physiotherapy* **1992**, *78*, 164–166. [CrossRef]
13. Alberton, C.L.; Fonseca, B.A.; Nunes, G.N.; Bergamin, M.; Pinto, S.S. Magnitude of vertical ground reaction force during water-based exercises in women with obesity. *Sports Biomech.* **2021**, 1–14. [CrossRef]
14. Nakazawa, K.; Yano, H.; Miyashita, M. Ground Reaction Forces during Walking in Water. *Med. Sport Sci.* **1994**, *39*, 28–34.
15. Barela, A.M.F.; Stolf, S.F.; Duarte, M. Biomechanical characteristics of adults walking in shallow water and on land. *J. Electromyogr. Kinesiol.* **2006**, *16*, 250–256. [CrossRef]
16. Barela, A.M.F.; Duarte, M. Biomechanical characteristics of elderly individuals walking on land and in water. *J. Electromyogr. Kinesiol.* **2008**, *18*, 446–454. [CrossRef]
17. de Brito Fontana, H.; Haupenthal, A.; Ruschel, C.; Hubert, M.; Ridehalgh, C.; Roesler, H. Effect of Gender, Cadence, and Water Immersion on Ground Reaction Forces During Stationary Running. *J. Orthop. Sports Phys. Ther.* **2012**, *42*, 437–443. [CrossRef] [PubMed]
18. Colado, J.C.; Garcia-Masso, X.; González, L.-M.; Triplett, N.T.; Mayo, C.; Merce, J. Two-Leg Squat Jumps in Water: An Effective Alternative to Dry Land Jumps. *Int. J. Sports Med.* **2010**, *31*, 118–122. [CrossRef] [PubMed]
19. Delevatti, R.; Alberton, C.; Kanitz, A.; Marson, E.; Kruel, L. Vertical ground reaction force during land-and water-based exercise performed by patients with type 2 diabetes. *Med. Sport.* **2015**, *11*, 2501.
20. Miyoshi, T.; Shirota, T.; Yamamoto, S.; Nakazawa, K.; Akai, M. Effect of the walking speed to the lower limb joint angular displacements, joint moments and ground reaction forces during walking in water. *Disabil. Rehabil.* **2004**, *26*, 724–732. [CrossRef]
21. Nunes, G.N.; Pinto, S.S.; Krüger, G.R.; Peyré-Tartaruga, L.A.; Andrade, L.S.; Mendes, G.F.; Krüger, V.L.; Pinheiro, R.B.; Marques, A.C.; Alberton, C.L. Kinetic parameters during land and water walking performed by individuals with Down Syndrome. *Gait Posture* **2020**, *79*, 60–64. [CrossRef]
22. Triplett, N.T.; Colado, J.C.; Benavent, J.; Alakhdar, Y.; Madera, J.; Gonzalez, L.M.; Tella, V. Concentric and Impact Forces of Single-Leg Jumps in an Aquatic Environment versus on Land. *Med. Sci. Sports Exerc.* **2009**, *41*, 1790–1796. [CrossRef] [PubMed]
23. Haupenthal, A.; Ruschel, C.; Hubert, M.; de Brito Fontana, H.; Roesler, H. Loading forces in shallow water running in two levels of immersion. *J. Rehabil. Med.* **2010**, *42*, 664–669.
24. Alberton, C.L.; Finatto, P.; Pinto, S.S.; Antunes, A.H.; Cadore, E.L.; Tartaruga, M.P.; Kruel, L. Vertical ground reaction force responses to different head-out aquatic exercises performed in water and on dry land. *J. Sports Sci.* **2015**, *33*, 795–805. [CrossRef]
25. de Brito Fontana, H.; Ruschel, C.; Haupenthal, A.; Hubert, M.; Roesler, H. Ground Reaction Force and Cadence during Stationary Running Sprint in Water and on Land. *Int. J. Sports Med.* **2015**, *36*, 490–493. [CrossRef]
26. de Onis, M. Development of a WHO growth reference for school-aged children and adolescents. *Bull. World Health Organ.* **2007**, *85*, 660–667. [CrossRef]
27. Yaghoubi, M.; Fink, P.W.; Page, W.H.; Shultz, S.P. Stationary Exercise in Overweight and Normal Weight Children. *Pediatri. Exerc. Sci.* **2019**, *31*, 52–59. [CrossRef]
28. Apte, S.; Prigent, G.; Stöggl, T.; Martínez, A.; Snyder, C.; Gremeaux-Bader, V.; Aminian, K. Biomechanical Response of the Lower Extremity to Running-Induced Acute Fatigue: A Systematic Review. *Front. Physiolo.* **2021**, *12*, 646042. [CrossRef]
29. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Laurence Erlbaum Associates: Mahwah, NJ, USA, 1988.

30. Alberton, C.L.; Zaffari, P.; Pinto, S.S.; Reichert, T.; Bagatini, N.C.; Kanitz, A.C.; Almada, B.P.; Kruel, L.F.M. Water-based exercises in postmenopausal women: Vertical ground reaction force and oxygen uptake responses. *Eur. J. Sport Sci.* **2021**, *21*, 331–340. [CrossRef] [PubMed]
31. Alberton, C.L.; Nunes, G.N.; Rau, D.G.D.S.; Bergamin, M.; Cavalli, A.S.; Pinto, S.S. Vertical Ground Reaction Force During a Water-Based Exercise Performed by Elderly Women: Equipment Use Effects. *Res. Q. Exerc. Sport* **2019**, *90*, 479–486. [CrossRef]
32. Torres-Ronda, L.; Schelling i del Alcázar, X. The Properties of Water and their Applications for Training. *J. Hum. Kinet.* **2014**, *44*, 237–248. [CrossRef] [PubMed]
33. Hayes, W.C.; Myers, E.R. Biomechanical considerations of hip and spine fractures in osteoporotic bone. *Instr. Course Lect.* **1997**, *46*, 431–438. [PubMed]
34. Alberton, C.L.; Pinto, S.S.; Cadore, E.L.; Tartaruga, M.P.; Kanitz, A.C.; Antunes, A.H.; Finatto, P.; Kruel, L.F. Oxygen Uptake, Muscle Activity and Ground Reaction Force during Water Aerobic Exercises. *Int. J. Sports Med.* **2014**, *35*, 1161–1169. [CrossRef] [PubMed]