 DOI: http://dx.doi.org/10.1590/S1980-6574201700040002

Original Article (short paper)

Effects of a deep-water running program on muscle function and functionality in elderly women community-dwelling

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Abstract — Aims: The aim of the study was to determine the effects of deep-water running on muscle function and functionality in community-dwelling old women. **Methods:** Older women (n=19) were randomly assigned to one of the two groups: deep-water running (DWR: n=09, 64.33±4.24 years, 75.15±12.53 kg, 160.45±7.52 cm; or control group CG: n=10, 64.40±4.22 years, 74.46±12.39 kg, 158.88±5.48 cm). The DWR group carried out 18 weeks of deep-water running, twice/week 50 min sessions. Dynamic isokinetic strength for the lower limb and functionality was assessed before and after intervention. **Results:** DWR group increased peak torque, total work and average power of the knee and hip flexors and extensors. Additionally showed better performance on gait speed, timed up and go test, five-times-sit-to-stand-test repetitions from a chair as well as the six-minute walk test. **Conclusion:** The deep-water running program was effective to improve muscle function and functionality.

Keywords: aging, aquatic exercise, strength, functionality

Introduction

Aging is characterized by a decreased physical capacity, functional decline and mobility limitation. These limitations may be explained in part by age-related neural and muscular system alterations[1]. A reduction in muscular fiber size occurs (atrophy), especially in the fast twitch fibers[2]. In addition, neural alterations such as, increased co-activation of the antagonist muscles and reduction on the recruitment and synchronism of the motor units are observed[1]. All together these alterations causes a decrease in strength[3] and power[4] which may result in difficulties to perform daily activities[5].

Strength and muscular power are considered predictors of functionality, specifically in older adults. Ascending and descending from stairs, as well as rising up from a chair, are tasks that require relative efforts ranging from 78 % to 88% of maximal torque capacity of older adults, almost double the generation required compared to young persons[6]. Rather than strength, muscle power has been strongly associated with tasks such as rising up from a chair. Depending on seat height, high angular velocities are required (122 to 186 °/s^{-1} and 141 to 224°/s^{-1} e.g. for knee and hip joints, respectively)[7], requiring fast muscle contractions

Practicing regular physical exercise may preserve functional capacity and the functionality of the aged population as well as mitigate the negative effects of aging[8]. Water-based exercises have been recommended to this population due to specific water properties that may maintain or improve functional movement[9].

In this view, water viscosity increases drag and creates difficulty to move the body through the water when exercising, that may result in improved muscle strength and also the rate of torque development[10]. Additionally, when combined with turbulence, the buoyancy forces cause instability and may be a stimulus to develop balance[11]. Deep-water running (DWR) is one form of water based exercise that is performed using a floatation device in which there is no foot contact with the bottom of the swimming pool, requiring greater hip and knee range of motion[12] and also greater muscle activity of lower limbs, hip and trunk[13]. Studies have demonstrated the effectiveness of DWR in the aging population through exhibiting an improvement in cardiorespiratory fitness[14], static and dynamic balance[15] and strength when combined with resistance training[16,17]. However, to our knowledge, no study has investigated the effects of an exclusive DWR program on strength and power in the lower limbs muscle of older adults, specifically on the hip flexor and extensor muscles, that together with knee muscles are responsible for quality of mobility in older people[18]. Thus, the aim of the present study was to determine the effects of a DWR program on hip and knee muscles strength, power output and functionality in older women.

Methods

Experimental Design

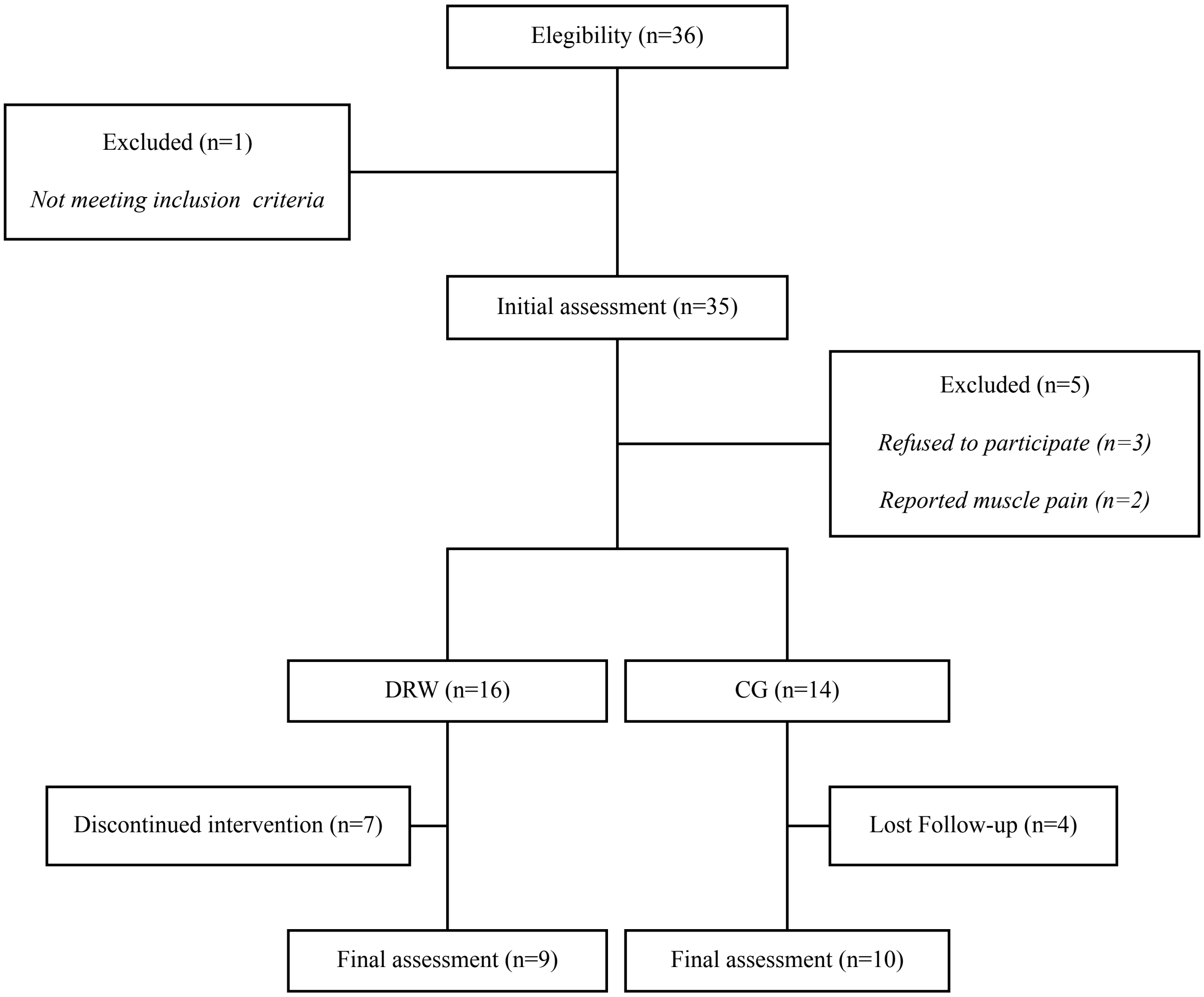
A pre-test and posttest design was conducted with community-dwelling old women. All participants partook in 3 nonconsecutive days of testing, including assessment of functionality, familiarization with the isokinetic dynamometer and assessment of dynamic isokinetic strength. After, participants were allocated into either a control group or intervention group in which the intervention group completed an aquatic exercise program. The program consisted of an 18-week DWR program compromising of 2 training sessions per week on nonconsecutive days, lasting 50 minutes. Subjects of the control group participated in baseline and post intervention testing sessions and were required to maintain their regular habits and refrain from unusual physical activities during the period of the study.

Subjects

Thirty-six women from the community were recruited for the study. The Physical Education Department of the Federal University of Paraná contacted participants between February and March of 2016 through local media, flyers and telephone. The program began in April of 2016. The inclusion criteria were: 60 years old or older, able to live independently in the community, present medical release for physical exercise and have no restrictions for pool entry (e.g., skin problems); not participating in a systematic physical exercise program during the 6 months that preceded the study. The exclusion criteria for the study were: the use of orthosis, history of labyrinthitis, uncontrolled diabetes, neuromuscular or severe osteoarticular diseases. Procedures were granted approval by the research ethics committee of the Dom Bosco College under the number 1672522.

One participant did not satisfy inclusion criteria due to altered balance and thus, was excluded from the study. During the initial assessments procedures, three women declined to participate due to personal reasons and two due to reporting muscle pain. Subsequently, thirty participants engaged in the program and were randomly allocated to either the intervention group (DWR; n=16) or the control group (CG; n=14). Seven participants from the DWR gave up participating due to health problems and four from the CG due to personal issues. At the end of the program nineteen women were assessed. The experimental design of the study is shown in Figure 1.

Figure 1. Schematic representation of participant recruitment and allocation.



Procedures

Participants attended the laboratory three times to perform the initial assessments. On the first day, the level of physical activity, through the international physical activity questionnaire (IPAQ) was assessed, as well as functionality, through a series of tests including 4 meter walking test (4MWT),[19] five times sit-to-stand-test (FTSST), the timed up and go test (TUGT),[20] the six-minute walk test (6MWT)[21] and the 10-meter walking speed test (10MWST)[22]. The order of the tests were randomly assigned and a rest interval of five minutes between tests was given to avoid fatigue effects

On the second day, a familiarization protocol with the isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) and procedures of the muscle function test had been performed in an attempt to reduce test-learning effects. On the third day, testing of muscular strength and power of the dominant lower limb was performed. The peak torque (N), total work (J) and average power (W) of the hip and knee flexors and extensors were evaluated at angular velocities of 60º/s and 180º/s, in order to evaluate different muscular demands, such as strength and muscle recruitment at the highest angular velocity, with the purpose of approaching to activities of daily life. The protocol composed of 2 sets of 3 repetitions of hip and knee flexion/extension movement in concentric mode, with a 120 second interval between sets. Data was acquired at a frequency of 1000 Hz. In both situations, the participants were verbally encouraged to produce 'the greatest possible effort'. Test order was reversed following the proximal/distal orientation of the participant to distal/proximal in the following participant. The intervals between assessment sessions were 48 hours and all tests were repeated after 18 weeks of training.

Water-based exercise program

The DWR program was performed for 18 weeks, two times per week (50min/session), totaling 36 sessions, to control the program more adequately the participants were divided into two groups. In addition, the participants were verbally encouraged to achieve the required exercise intensity. Activities were conducted in a 25-meter swimming pool, with a depth of 1.35 meters and water temperature controlled between 28ºC to 30ºC.

The first two weeks consisted of a familiarization period with the aquatic environment, the flotation vest and the Borg Rating of Perceived Exertion Scale (RPE) (Borg, 1982). Exercise intensity was controlled using the RPE, with progressive increment from 12 to 17 on the Borg scale (6-20 points), according to the American College of Sports Medicine's recommendations for aerobic exercises[8]. Each session included a 10-minute warm-up, 30 minutes of DWR and a 10 minute cool down period. Participants performed exercises at a low intensity, at an RPE of 12-13 during the weeks 3-8. Exercise intensity was increased by amplifying movement speed during the weeks 9-13 (RPE 14-15). Finally, during the 5 last weeks, subjects were requested to perform exercise using their maximal voluntary speed (RPE 16-17). Stretching exercises were performed in the last 10 minutes of the session as a cool down activity (Table 1). The CG was required to maintain their regular activities of daily living (ADLs) and physical activities during the period of study. At the end of the experimental period they were invited to engage in the program.

Table 1 – Progression of the water-based exercise program

Weeks	Duration (min) and description of exercise	Intensity (RPE)
1-2	50 min of familiarization period with the aquatic environment, the flotation vest and the Borg Rating of Perceived Exertion Scale	-
3-8	10 min warm-up, 30 min of DWR, 10 min cool down	12-13
9-13	10 min warm-up, 30 min of DWR, 10 min cool down	13-15
14-18	10 min warm-up, 30 min of DWR, 10 min cool down	15-17

Statistical analysis

A priori, sample size was calculated using G*Power 3.1 software, based on the study of Tsourlou, Benik, Dipla, Zafeiridis, Kellis[9].To meet parameter assumptions for the ANOVA test, 95% confidence level, maximum sampling error of 5% and a statistical power of 80%, a minimum of 12 participants were required. A further, 30% were added for possible data loss or refusal to participate and a minimum of 16 constituted the total sample (DWR = 8; CG = 8).

A sample power was calculated retrospectively based on strength of the knee muscle extensor (DWR: mean=98 N, SD= ±22, n=9; CG: mean= 66 N, n=10, SD=27), resulting in a sampling power of 94 %. Strength of the Knee extensor muscle was used due to relevance of the lower limb strength to perform daily living activities such as ascending and descending stairs, rising from a chair[23] and to avoid falls[24]. Power analysis was calculated using OpenEpi v. 3. Data normality and homogeneity of variance were tested using Shapiro-Wilk and Levene tests, respectively. To compare initial participants characteristics an independent t-test was performed. For comparison between group and repeated-measures (pre and post-training periods), a mixed design ANOVA with a Bonferroni post hoc were carried out. When differences between-groups were observed in the initial values, an analysis of covariance (ANCOVA) was applied using the initial data as covariates to compare the data of the post-test, disregarding the initial differences. In addition, Pearson's correlation coefficient *r* was determined to check the magnitude of observed effect, considering $r=0.10$ as small effect, $r=0.30$ as medium effect and $r=0.50$ as large effect[25]. The significance level was set at $p<0.05$ and all statistical analyses were performed using SPSS 22.0 software.

Results

Nine women in the intervention group and ten women in the control group took part in this study (DWR: n=09, 64.33±4.24 years, 75.15±12.53 kg, 160.45±7.52 cm; CG: n=10, 64.40±4.22 years, 74.46±12.39 kg, 158.88±5.48 cm). All participants performed evaluations before and after the training period. No differences were noted in age and initial anthropometric characteristics between-groups ($p>0.05$). The participants were classified according to the initial level of physical activity, by the international physical activity questionnaire (IPAQ), as active 73.68% (DWR: n=6, CG: n=8) and insufficiently active 26.31% (DWR: n=3, CG: n=2). Training session mean attendance rate was 91.36%

Muscle Function

At an angular velocity of 60º/s, the DWR group presented greater peak torque and total work of hip flexors and extensors as well as the average power of hip extensors ($p<0.05$) after intervention. There was also a group and time interaction to the total work of hip extensors, with a large effect size ($F_{(1,17)}=9.102$, $p=0.008$, $r=0.59$). Post intervention, at an angular velocity of 180º/s, an increased peak torque, total work and average power of the knee flexors in the DWR was observed ($p<0.05$). There was also a group and time interaction to the peak torque, with a medium effect size ($F_{(1,17)}=4.580$, $p=0.047$, $r=0.46$), of the total work of hip extensors ($F_{(1,17)}=5.777$, $p= 0.028$, $r=0.50$) and average power of the hip flexors ($F_{(1,17)}=6.872$, $p=0.018$, $r=0.53$), both with a large effect size. The results are shown in table 2.

At an angular velocity of 60º/s, the DWR group displayed greater peak torque, total work and average power of knee flexors and extensors after the intervention ($p<0.05$). There was also a group and time interaction to the peak torque ($F_{(1,17)}=7.075$, $p=0.017$, $r=0.54$) and total work of the knee flexors ($F_{(1,17)}=11.304$, $p=0.004$, $r=0.63$), both with a large effect size. At an angular velocity of 180º/s, the DWR group post intervention displayed an increased peak torque total work and average power of knee flexors ($p<0.05$). There was also a group and time interaction to the peak torque ($F_{(1,17)}=7.075$, $p=0.017$, $r=0.54$), total work ($F_{(1,17)}=6.900$, $p=0.018$, $r=0.54$) and average power of the hip flexors ($F_{(1,17)}=8.819$, $p=0.009$, $r=0.58$), all with a large effect size. The results are shown in table 3.

Table 2 – Isokinetic variables for the flexors and extensors of the hip at the angular velocity of 60°/s and 180°/s

ISOKINETIC VARIABLES	DWR		CG		p	ES	DWR		CG		p	ES
	PRE	POST	PRE	POST	(group*time)		PRE	POST	PRE	POST	(group*time)	
	60º/seg^{-1}						180º/seg^{-1}					
PT_{EXT} (N)	63.6 (12.5)	77.0* (24.0)	64.7 (16.2)	64.2 (20.0)	0.078	0.41	58.8 (9.5)	72.1* (20.7)	51.0 (8.2)	49.3 (15.9)	0.047#	0.46
PT_{FLEx} (N)	59.5 (26.0)	69.1* (25.4)	47.1 (11.4)	52.0 (20.9)	0.388	0.20	50.8 (15.5)	56.5 (15.0)	41.8 (7.7)	41.3 (15.5)	0.182	0.32
TW_{EXT} (J)	187.8 (34.9)	273.7* (79.3)	218.4 (65.5)	218.7 (86.0)	<0.01#	0.59	177.9 (44.1)	223.6* (50.0)	167.1 (36.0)	149.2 (73.2)	0.028#	0.50
TW_{FLEX} (J)	177.4 (81.4)	222.1* (100)	154.9 (44.9)	163.5 (76.4)	0.114	0.37	139.8 (45.9)	188.8* (57.1)	109.7 (23.2)	130.0 (67.6)	0.235	0.28
POW_{EXT} (W)	35.7 (8.2)	42.1* (13.2)	32.5 (7.9)	33.8 (11.0)	0.171	0.32	61.8 (16.9)	78.3* (22.4)	53.2 (12.9)	51.2 (26.6)	0.074	0.42
POW_{FLEX} (W)	32.0 (11.5)	35.1 (12.6)	26.6 (5.4)	27.04 (9.7)	0.214	0.30	48.4 (14.5)	63.6* (22.5)	41.6 ± 10.39	40.6 (17.9)	0.018#	0.53

Note: Data presented as mean (±standard deviation). Legend: PT = peak torque, TW = total work, POW = average power, N = Newton, J = Joules, W = Watts. Significance level p < 0.05 (*time effect; #group*time). ES = effect size.

Table 3 – Isokinetic variables for the flexors and extensors of the knee at the angular velocity of 60°/ s and 180°/ s

ISOKINETIC VARIABLES	DWR		CG		p	ES	DWR		CG		P	ES
	BEFORE	AFTER	BEFORE	AFTER	(group* time)		BEFORE	AFTER	BEFORE	AFTER	(group* time)	
	60º/seg^{-1}						180º/seg^{-1}					
PT_{EXT} (N)	87.7[a] (20.7)	98.4* (22.6)	63.9[a] (19.2)	66.1 (27.8)	0.199	0.94	60.3[a] (10.5)	65.2 (11.4)	46.1[a] (14.1)	50.5 (16.4)	0.919	0.87

PT_{FLEX} (N)	58.6 (16.0)	78.0* (22.1)	66.7 (17.8)	69.4 (18.3)	0.017$^{\#}$	0.54	39.4 (8.7)	55.1* (12.2)	47.5 (10.6)	48.91 (12.7)	0.016$^{\#}$	0.54
TW_{EXT} (J)	295.5^{a} (82.8)	342.3* (93.5)	217.3^{a} (67.4)	228.6 (100.3)	0.146	0.94	221.0^{a} (48.3)	250.7 (54.5)	152.8^{a} (57.7)	171.2 (73.1)	0.633	0.82
TW_{FLEX} (J)	211.7 (54.0)	280.8* (85.3)	226.2 (39.7)	229.6 (61.6)	0.004$^{\#}$	0.63	140.6 (32.5)	210.3* (50.1)	162.7 (31.8)	171.7 (55.4)	0.018$^{\#}$	0.54
POW_{EXT} (W)	50.2^{a} (11.7)	60.8* (17.7)	38.7^{a} (12.0)	41.1 (16.0)	0.052	0.91	96.0^{a} (17.2)	109.8 (24.0)	67.3^{a} (29.4)	73.9 (33.6)	0.493	0.83
POW_{FLEX} (W)	35.6 (10.5)	46.7* (15.7)	39.2 (9.1)	41.1 (11.9)	0.057	0.44	59.1 (13.4)	88.0* (23.6)	71.1 (17.8)	71.2 (24.4)	<0.01$^{\#}$	0.58

Note: Data presented as mean (±standard deviation). Legend: PT = peak torque, TW = total work, POW = average power, N = Newton, J = Joules, W = Watts. Significance level p < 0.05 (*time effect; #group*time). a = ANCOVA. ES = effect size.

Functionality

After the intervention, the DWR group presented greater gait speed, five-repetition sit-to-stand tests, timed up and go test, 10-meter walking speed test and (p<0.05). The CG presented a reduction in the distance traveled on the 6MWT after the period between the tests (p<0.05). There was also a group and time interaction to the gait speed ($F_{(1,17)}$=12.167, p=0.003, r=0.64), TUGT ($F_{(1,17)}$=8.649, p=0.009, r=0.58), 10MWST ($F_{(1,17)}$=7.237, p=0.015, r=0.65) e 6MWT ($F_{(1,17)}$=20.496, p=< 0.01, r=0.74), all with a large effect size, in which the DWR presented greater results in comparison to the CG in the post-test. The results are shown in table 4.

Table 4 - The functional performance tests.

	DWR		**%**	**CG**		**%**	**P (group* time)**	**ES**
	BEFORE	**AFTER**		**BEFORE**	**AFTER**			
4MWT (m/s)	1.1 (0.1)	1.6* (0.2)	43.9	1.3 (0.2)	1.3 (0.1)	5.3	0.003$^{\#}$	0.64
FTSST (s)	9.3 (0.8)	8.5* (1.2)	-8.9	9.0 (1.4)	8.9 (0.9)	-0.6	0.06	0.44
TUGT (s)	6.5 (0.7)	5.8* (0.4)	-10.9	6.3 (0.8)	6.2 (1.0)	-0.3	<0.01$^{\#}$	0.58
10MWST (s)	3.5 (0.4)	3.0* (0.2)	-14.4	3.5 (0.2)	3.4 (0.4)	-3.3	0.015$^{\#}$	0.65
6MWT (m)	555.5 (63.0)	597.8* (53.2)	7.6	546.8 (51.6)	526.1* (50.1)	-3.7	<0.01$^{\#}$	0.74

Note: Data presented as mean (standard deviation). Legend: FTSST- Five times-sit-to-stand-test, TUGT= Timed Up and Go test, 10MWST = 10-Meter Walking Speed test, 6MWT = Six-Minute Walk test, m/s = meters/second, s = second, m = meters. Significance level p < 0.05 (*time effect; #group*time). ES = effect size.

Discussion

The main findings of the current study was that 18 weeks of a DWR program was able to improve strength and power of the hip and knee extensor and flexor muscles in comparison with a control group. Additionally, participants showed improved performance in all functional tests. Furthermore, moderate and large effect sizes were found for the entire group and time interaction statistical differences, which reinforces the relevance of the results

Due to differences in training program contents and methods of strength assessment it is difficult to compare the strength gains observed in the present study with those of other studies. In addition, no study has assessed strength of the hip extensors and flexors muscle after DWR. Meredith-Jones, Legge, Jones[16] reported isokinetic peak torque increases of 32% and 33% for knee extensors and flexors muscles respectively, however the exercise program combined DWR with 90 seconds of specific strength exercises for the upper and lower limbs. The results of the current study were lower, yet significant (12%) for the knee extensors and similar for knee flexors (33%) at angular velocities of 60º/s^{-1} and (39%) at 180º/s^{-1}.

Reichert, Kanitz, Sudatti, Carvalho, Machado, Martins[26] compared the effects of an interval DWR with a combination of endurance training plus strengthening exercises of the lower limbs. They found a lower strength improvement compared to those of the present study (6%) after DWR and (9.9%) after concurrent training of the knee extensor muscles group, however no differences were observed for the knee flexors. In our study, a higher rate of improvement may be explained by exercise intensity, due to participants being encouraged to increase the velocity of displacement throughout the program which was controlled using the rate of perceived exertion (Borg 12-17). In order to increase displacement velocity, faster limb movements are required. In this view, considering that water resistance in the presence of water turbulence increases as a log function of velocity, the muscular effort necessary to move the body increases as well[27].

Despite the importance of these muscles group to perform functional activities such as gait, sitting to standing from a chair[28] and ascending and descending stairs[29], to our knowledge, there is no study that has assessed the effects of DWR on hip extensors and flexors. In this view, the current study found greater strength and power enhancement of the hip extensors and flexor muscles after DWR, which may contribute to improved functionality.

Kaneda, Wakabayashi, Sato, Uekusai, Nomura[30] investigated the activity of the lower limb muscles in DWR and found high activity of the biceps femoris during the backward (hip extension) and forward swing phase (hip flexion). High percentages of maximal voluntary contraction were associated with the large range of motion at the hip and knee joint in DWR. In addition, due to the short duration of the backward phase, great force must be exerted to swing the leg backward. During the swing forward, high percentage of maximal voluntary contraction of the rectus femoris was also observed because of the substantial force necessary to overcome water resistance when moving the leg forward. Indeed, during the displacement of the body segment through the water, both the agonist and antagonist muscles are activated due to water resistance being exerted in all directions of movement[27]. Thus, the DWR seems to promote necessary demand resulting in greater improvement in the strength and power of the lower limb muscles. Additionally, participants displayed a significant improvement in functional performance in the present study. This may be explained through the increase in strength and power of the hip and knee extensors and flexors aforementioned. Strength and power are strongly related to physical function[31]. Participants displayed significant improvements in the FTSST (8.9 % decrease in time after intervention). To perform this test it is necessary to produce a rapid torque of the knee and hip muscles[5,7].

Reichert, Kanitz, Sudatti, Carvalho, Machado, Martins[26] also found improvements after different DWR programs, in terms of interval and continuous training methods respectively (46% and 49%), which were higher than what was observed in our study. However, the comparison may be difficult due to differences in functional tests as the previous study assessed lower limb strength using a 30 second sit to stand test, furthermore the study lasted 28 weeks.

There were statistically significant increases in both, self-selected and maximal gait speed, walking distance in the 6MTW and timed up and go tests. Kaneda, Sato, Wakabayashi, Nomura[13] compared the effects of a regular water exercise program for the lower limbs in addition to walking in different directions with a DWR program in usual and maximum gait speed. Contradictory to our findings, no differences were found after the intervention in both groups, in which we observed a significant improvement in self-selected (11%) and maximal gait velocity (14%). This may be due to different intervention durations, in the present study the intervention period lasted 18 weeks (36 sessions) and the exercise intensity ranged from somewhat hard to very hard (RPE 12-17), whilst, in the Kaneda, Sato, Wakabayashi, Nomura study the intervention lasted 12 weeks (24 sessions) and exercise intensity was light (RPE 11), which may explain for discrepancies between the results.

Reichert, Kanitz, Sudatti, Carvalho, Machado, Martins[26] also verified the effects of DWR programs (continuous versus interval training) in functional fitness in which they found an improvement in the distance of the 6MWT (12%) only in the DWR interval-training group. The improvement in our study was less, nonetheless significant (7.6%) which also may be due to the duration of intervention.

It is important to highlight that all of these tests, except the FTSST, assess walking ability, which is closely related to the activities performed during the water exercise program (DWR). This suggests that the tests were able to capture the muscle function improvement obtained through water exercise program. The estimated relative effort during walking at the hip and knee extensors muscles are 27% and 30% of the maximal strength respectively, thus maximal strength increases may result in less absolute effort to walk[23]. In addition, gait velocity has been considered as an indicator of vitality and health[32]. Walking velocities equal or higher than 1.0 m/s^{-1} are related to healthy aging and increased life expectation[32]. These relationships are supported by the fact that, walking requires energy, movement control and integration of multiple systems such as cardiorespiratory, nervous and musculoskeletal systems[32]. Whether decreasing gait speed may reflect the damage on these systems, it is plausible to consider that increases in gait speed observed after exercise interventions may reflect an improvement of these systems.

It should be noted that a significant dropout rate was observed in both groups especially in the exercise group, however the statistical power of 94% gave sufficient generalizability for the aging population.

Practical Applications

The results of the present study provides evidence that the DWR program is effective in improving muscle function (strength and power) of the lower limbs and functionality in older adults. Thus, DWR is an alternative aquatic exercise to be considered in order to counteract muscular and functional age-related decline and also maintain independence and promote successful aging. As displayed by the findings of our study, physical education teachers and health professionals should consider the DWR in order to develop effective interventions for older people.

References

1. Clark BC, Manini TM. Functional consequences of sarcopenia and dynapenia in the elderly. Curr Opin Clin Nutr Metab Care. 2010;13(3):271-276. doi:10.1097/MCO.0b013e328337819e.

2. Hughes VA, Frontera WR, Wood M, Evans WJ, Dallal GE, Roubenoff R, et al. Longitudinal muscle strength changes in older adults: influence of muscle mass, physical activity, and health. J Gerontol A Biol Sci Med Sci. 2001;56(5):B209-B217. doi:10.1093/gerona/56.5.B209.
3. Delmonico MJ, Harris TB, Visser M, Park SW, Conroy MB, Velasquez-Mieyer P, et al. Longitudinal study of muscle strength, quality, and adipose tissue infiltration. Am J Clin Nutr. 2009;90(6):1579-1585. doi:10.3945/ajcn.2009.28047. INTRODUCTION.
4. Candow DG, Chilibeck PD. Differences in size, strength, and power of upper and lower body muscle groups in young and older men. J Gerontol A Biol Sci Med Sci. 2005;60(2):148-156. doi:60/2/148 [pii].
5. Brady AO, Straight CR, Evans EM. Body Composition, Muscle Capacity, and Physical Function in Older Adults: An Integrated Conceptual Model. J Aging Phys Act. 2014;22(3):441-452. doi:10.1123/JAPA.2013-0009.
6. Hortobágyi T, Mizelle C, Beam S, DeVita P. Old adults perform activities of daily living near their maximal capabilities. J Gerontol A Biol Sci Med Sci. 2003;58(5):M453-M460. doi:10.1093/gerona/58.5.M453.
7. Schenkman M, O'Riley PO, Pieper C. Sit to stand from progressively lower seat heights: Alterations in angular velocity. Clin Biomech. 1996;11(3):153-158. doi:10.1016/0268-0033(95)00060-7.
8. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, Skinner JS. Exercise and physical activity for older adults. Med Sci Sports Exerc. 2009;41(7):1510-1530. doi:10.1249/MSS.0b013e3181a0c95c.
9. Tsourlou T, Benik A, Dipla K, Zafeiridis A, Kellis S. The effects of a twenty-four-week aquatic training program on muscular strength performance in healthy elderly women. J strength Cond Res. 2006;20(4):811-818. doi:10.1519/R-18455.1.
10. Bento P, Pereira G, Ugrinowitsch C, Rodacki ALF. The Effects of a Water-Based Exercise Program on Strength and Functionality of Older Adults. J Aging Phys Act. 2012;20:469-501.
11. Cebolla EC, Rodacki ALF, Bento PCB. Balance, gait, functionality and strength: Comparison between elderly fallers and non-fallers. Brazilian J Phys Ther. 2015;19(2):146-151. doi:10.1590/bjpt-rbf.2014.0085.
12. Kaneda K, Sato D, Wakabayashi H, Nomura T. EMG activity of hip and trunk muscles during deep-water running. J Electromyogr Kinesiol. 2009;19(6):1064-1070. doi:10.1016/j.jelekin.2008.11.001.
13. Kaneda K, Wakabayashi H, Sato D, Nomura T. Lower extremity muscle activity during different types and speeds of underwater movement. J Physiol Anthropol. 2007;26(2):197-200. doi:10.2114/jpa2.26.197.
14. Broman G, Quintana M, Lindberg T, Jansson E, Kaijser L. High intensity deep water training can improve aerobic power in elderly women. Eur J Appl Physiol. 2006;98(2):117-123. doi:10.1007/s00421-006-0237-2.
15. Kaneda K, Sato D, Wakabayashi H, Hanai A, Nomura T. A comparison of the effects of different water exercise programs on balance ability in elderly people. J Aging Phys Act. 2008;16(4):381-392.
16. Meredith-Jones K, Legge M, Jones LM. Circuit Based Deep Water Running Improves Cardiovascular Fitness, Strength and Abdominal Obesity in Older, Overweight Women Aquatic Exercise Intervention in Older Adults. Med Sport. 2009;13(1):5-12. doi:10.2478/v10036-009-0002-9.
17. Kanitz AC, Delevatti RS, Reichert T, Liedtke GV, Ferrari R, Almada BP, et al. Effects of two deep water training programs on cardiorespiratory and muscular strength responses in older adults. Exp Gerontol. 2015;64:55-61. doi:10.1016/j.exger.2015.02.013.
18. Dean JC, Kuo AD, Alexander NB. Age-related changes in maximal hip strength and movement speed. J Gerontol A Biol Sci Med Sci. 2004;59(3):286-292. doi:10.1093/gerona/59.3.M286.
19. Guralnik J, Simonsick EM, Feruucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol Biol Sci. 1994;49(2):M85-M94.
20. Podsiadlo D, Richardson S. The Timed "Up & Go": A Test of Basic Functional Mobility for Frail Elderly Persons. J Am Geriatr Soc. 1991;39(2):142-148. doi:10.1111/j.1532-5415.1991.tb01616.x.
21. Rikli R, Jones J. Development and validation. J Aging Phys Act. 1999;7:129-161. doi:10.1093/geront/gns071.
22. Tibaek S, Holmestad-Bechmann N, Pedersen TB, Bramming SM, Friis AK. Reference values of maximum walking speed among independent community-dwelling Danish adults aged 60 to 79 years: A cross-sectional study. Physiother (United Kingdom). 2015;101(2):135-140. doi:10.1016/j.physio.2014.08.005.
23. Byrne C, Faure C, Keene DJ, Lamb SE. Ageing, Muscle Power and Physical Function: A Systematic Review and Implications for Pragmatic Training Interventions. Sport Med. 2016;46(9):1311-1332. doi:10.1007/s40279-016-0489-x.
24. Bento PCB, Pereira G, Ugrinowitsch C, Rodacki ALF. Peak torque and rate of torque development in elderly with and without fall history. Clin Biomech. 2010;25(5):450-454. doi:10.1016/j.clinbiomech.2010.02.002.
25. Field A. Descobrindo a Estatística Usando O SPSS [Recurso Eletrônico. 2ª Edição. Porto Alçegre: Artemed; 2009.
26. Reichert T, Kanitz AC, Sudatti R, Carvalho N, Machado B, Martins LF. Continuous and interval training programs using deep water running improves functional fitness and blood pressure in the older adults. Age (Dordr). 2016;38(20):1-9. doi:10.1007/s11357-016-9882-5.
27. Becker BE. Aquatic Therapy: Scientific Foundations and Clinical Rehabilitation Applications. PM R. 2009;1(9):859-872. doi:10.1016/j.pmrj.2009.05.01728.
28. Inkster LM, Eng JJ, MacIntyre DL, Jon Stoessl A. Leg muscle strength is reduced in Parkinson's disease and relates to the ability to rise from a chair. Mov Disord. 2003;18(2):157-162. doi:10.1002/mds.10299.
29. Nadeau S, McFadyen BJ, Malouin F. Frontal and sagittal plane analyses of the stair climbing task in healthy adults aged over 40 years: What are the challenges compared to level walking? Clin Biomech. 2003;18(10):950-959. doi:10.1016/S0268-0033(03)00179-7.
30. Kaneda K, Wakabayashi H, Sato D, Uekusa T, Nomura T. Lower extremity muscle activity during deep-water running on

self-determined pace. J Electromyogr Kinesiol. 2008;18(6):965-972. doi:10.1016/j.jelekin.2007.04.004.

31. Hazell T, Kenno K, Jakobi J. Functional benefit of power training for older adults. J Aging Phys Act. 2007;15(3):349-359. doi:10.1038/sj.mp.4001719.
32. Studenski S, Perera S, Patel K. Gait Speed and Survival in Older Adults. Jama. 2011;305(1):50-58. doi:10.1001/jama.2010.1923. Gait.

Acknowledgments

The authors would like to acknowledge the support of Pontifical University Catholic of Parana – PUCPR for their general assistance.

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Manuscripted received on August 7, 2017
Manuscripted accepted on October 4, 2017