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Validity of Values for Metabolic Equivalents of Task During Submaximal All-Extremity Exercise and Reliability of Exercise Responses in Frail Older Adults

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Background and Purpose. Physical therapists and rehabilitation professionals in hospital and long-term care centers are using all-extremity semirecumbent exercise machines in their treatment programs. This study was undertaken to investigate the concurrent validity of values for software-generated metabolic equivalents of task (MET) from an all-extremity semirecumbent exercise machine and directly measured values for MET from a portable metabolic unit across a range of submaximal exercise intensities. A second purpose of this study was to determine the test-retest reliability of oxygen consumption and heart rate responses in older adults between standardized sessions of submaximal all-extremity aerobic exercise.

Subjects and Methods. The study participants were 18 older adults (mean age=82 years, SD=5; 3 women, 15 men) who were living in long-term care centers and who completed 2 test sessions of a standardized exercise protocol 1 week apart. The exercise protocol included a warm-up period, three 4-minute stages of exercise at incremental workload levels, and a cool-down period. The breath-by-breath metabolic data from the portable metabolic unit, heart rate, MET values from the exercise machine, Borg Rating of Perceived Exertion, and watts were recorded continuously throughout the exercise protocol.

Results. The concurrent validity of the MET values from the exercise machine and the portable metabolic unit ranged from very good to excellent on both day 1 and day 2 (r=.85–.97). The test-retest reliability of subjects' heart rate responses and MET values from the portable metabolic unit was moderate to high across submaximal exercise intensities (intraclass correlation coefficients [2,1]=.85–.91).

Discussion and Conclusion. The exercise machine software-generated MET values were representative of directly measured oxygen consumption values across a range of submaximal intensities during all-extremity semirecumbent exercise in older adults with multisystem impairments.

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Aerobic exercise options are limited for older adults with multisystem impairments, such as cognition, balance, weight-bearing ability, coordination, strength (force-generating capacity), or cardiorespiratory function. Available aerobic exercise options include using traditional exercise bikes, rowing machines, or steppers; walking or using stairs; using arm or leg ergometers in a sitting position; or using treadmills with body-weight–support systems. Simultaneous use of the arms and legs during all-extremity semirecumbent exercise would decrease localized muscle pain or fatigue associated with arm cranking or leg cycling exercise, increase the volume of muscle mass involved in exercise, reduce the likelihood of discontinuation of exercise because of localized arm or leg muscle pain or fatigue, and eliminate the requirement for partial to full weight-bearing capability to participate in aerobic exercise.[1] Aerobic fitness equipment that could accommodate standing balance and lower-extremity impairments and promote whole-body exercise for optimal aerobic fitness training would fill a current gap in exercise equipment options for older adults.

Exercise that can be performed by older adults with multiple impairments will be important for addressing morbidity related to frailty with aging, including dependency, disability, falls, hospitalization, admission to long-term care centers, and associated mortality.[2–5] There is evidence that exercise training, largely resistance exercise, in older adults in institutions is important for maintaining physical performance.[6] The few available studies on aerobic exercise training in older adults (>80 years of age) have shown increased peak oxygen consumption ($\dot{V}O_2$) and decreased systolic blood pressure (BP)[7] as well as a relative increase in peak $\dot{V}O_2$ (14% for men and 13% for women compared with control groups).[8] Residents of assisted-living facilities (mean age=85.5 years, SD=6.6) who exercised ≥9 minutes per week using an all-extremity semirecumbent machine had significantly improved mobility (P=.002) compared with those who exercised for shorter durations.[9]

All-extremity semirecumbent exercise machines, such as the BioStep Clinical Pro Semi-Recumbent Elliptical Cross Trainer* and the NuStep TRS 4000 Recumbent Cross Trainer,† provide a new mode of seated aerobic exercise training with both arms and legs contributing to work output. These exercise trainers are ideal for accommodating impairments of the lower or upper extremities, weight-bearing ability, balance, coordination, or gait in older adults.[10] However, research addressing the validity of software-generated aerobic fitness values and the reliability of these values during all-extremity exercise is limited.[11] Therefore, this study was undertaken to investigate the concurrent validity of values for software-generated metabolic equivalents of task (MET‡) from an all-extremity semirecumbent exercise machine (NuStep) and directly measured values for MET from a portable metabolic unit (K4b^2§) across a range of submaximal exercise intensities. A second purpose was to determine the test-retest reliability of heart rate (HR) responses and $\dot{V}O_2$ in older adults between standardized sessions of submaximal all-extremity aerobic exercise.

* Biodex Medical Systems, 20 Ramsay Rd, Shirley, NY 11967-4704.
† NuStep Inc, 5111 Venture Dr, Suite 1, Ann Arbor, MI 48108.
‡ 1 MET=3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$.
§ Cosmed USA Inc, 2211 N Elston Ave, Suite 305, Chicago, IL 60614.

Method

Subjects

Older adults living in long-term care centers were recruited. Subjects were included if they were 70 years of age or older, scored 24 or higher on the Mini-Mental State Examination (MMSE),[12,13] and had physician approval to participate in the study. The American College of Sports Medicine (ACSM) guidelines for absolute and relative contraindications for exercise testing were used as exclusion criteria.[14] The absence of these exclusion criteria, including a range of cardiac, neurological, and musculoskeletal symptoms and conditions, was confirmed by each subject's physician. The number of subjects required for the study was determined as described by Hulley et al[15] (Appendix 6.C, Tab. 6.C: α=.05, power=80%). The primary variable was the correlation coefficient (Pearson r), indicating the minimum expected agreement between software-generated NuStep and directly-measured K4b^2 MET values. Thirteen subjects were required to declare a Pearson r correlation coefficient of ≥.70 to be statistically significant. However, with an expected dropout rate of about 30% in this older population, a minimum sample size of 17 subjects was required.

The demographic characteristics of the subjects (Tab. 1) , including their age, height, body mass, type of gait aid, date of admission to long-term care center, number of health conditions, and daily medications, were obtained from a review of their medical charts. Subjects were visited individually in their rooms to complete the MMSE. Informed written consent was obtained from all subjects prior to participation.

Over the duration of the study, 25 subjects were recruited. Several subjects withdrew at various stages of testing, which required continued recruitment to obtain the calculated sample size. Seven subjects withdrew from the study; 3 were not comfortable wearing the face mask, 2 asked to stop exercising 4 minutes into the required 12 minutes of exercise, 1 had a nonsymptomatic irregular HR response during exercise, and 1 was not well enough to complete the testing sessions. No adverse events associated with exercise testing occurred during the study. Data were collected for 18 subjects (15 men: mean age=82.2 years, SD=5.9, range=73–93; 3 women: mean age=83.7 years, SD=1.2, range=83–85). The sex ratio in our group of subjects was not representative of the usual mix in older age[16] because 83% of our study subjects were men recruited from a veteran's care program. The study group had an average of 7.7 (SD=2.8, range=4–15) chronic health conditions and took a daily average of 11.8 (SD=4.3, range=5–19) prescription medications, including β-blockers (n=14).

Table 1.
Descriptive Characteristics of the Study Sample (N=18)

Characteristic	$\bar{X}$	SD	Range
Age (y)	82.4	5.4	73–93
Body mass index (kg/m^2)	25.9	5.1	19.1–36.8
Mini-Mental State Examination score[a]	26.9	2.1	24–30
Time since entry into long-term care residence	2.2 y	4.6 y	1 mo–20 y
Assistive device used (no. of subjects)			
None	2		
Cane	3		
Rolling walker	5		
Standard walker	1		
Wheelchair (6 self-propelled, 1 electric)	7		
Chronic health conditions (no. of subjects)			
Visual impairment	14		
Cardiovascular disease	12		
Osteoarthritis	11		
Memory impairment, gastroesophageal reflux disease	8		
Carcinoma, chronic renal failure, dermatitis, hearing impairment, hypertension, neurogenic bowel and bladder	7		
Previous fracture	6		
Hyperthyroidism, anemia	5		
Osteoporosis	4		
Hyperlipidemia, lumbar spinal stenosis, total hip arthroplasty, pulmonary fibrosis, seizure disorder, Crohn disease	3		
Depression, diabetes	2		
Personality disorder, colitis, vertigo, Paget disease, paraplegia, poliomyelitis, Parkinson disease	1		

[a] Total score=30.

Instrumentation

The NuStep is a hybrid semirecumbent bicycle and stair climber machine (Fig. 1) with a range of 10 workload levels. Each arm handle is coupled with a contralateral foot pedal, allowing the user to exercise the upper and lower extremities by using a reciprocal forward and backward motion. Exercise parameters displayed continuously on the NuStep liquid crystal display (LCD) panel include stepping rate, workload level, and accumulated exercise duration. To obtain continuous feedback for HR during exercise, subjects wore an HR monitor (Polar Vantage NV[‖]) around the chest at the level of the xiphisternum. The Polar Vantage NV chest strap relayed HR via telemetry, and the HR was displayed on the NuStep LCD panel. The NuStep LCD touch screen panel could be manipulated to show instantaneous MET values, watts, total number of steps taken, or expended calories. The NuStep instantaneous MET values were software generated from power output (watts) and subject body mass.

The K4b^2 is a portable, breath-by-breath metabolic system for measuring $\dot{V}O_2$ and carbon dioxide production, calculating the respiratory exchange ratio (RER), and reporting HR throughout exercise. The K4b^2 is a lightweight (925-g) unit that is worn on a subject's torso and that uses telemetry to send data from the exercising subject. Subjects wear a face mask equipped with a turbine flowmeter to allow real-time collection of $\dot{V}O_2$ data. Previous research comparing the K4b^2 with the Douglas bag method over a range of cycling exercise intensities, from rest to 250 W,[17] showed no significant differences between K4b^2 and Douglas bag $\dot{V}O_2$ values; these data suggested that the K4b^2 portable metabolic system was acceptable for measuring $\dot{V}O_2$ values over this range of exercise intensity. The K4b^2 was

[‖] Polar Electro Inc, 1111 Marcus Ave, Suite M15, Lake Success, NY 11042-1034.

Figure 1.
Subject performing the submaximal exercise protocol on the NuStep TRS 4000 Recumbent Cross Trainer.

calibrated according to the manufacturer's instructions prior to each exercise test session and set up for transfer of collected data to a laptop computer via telemetry. Data collection with the $K4b^2$ began at the start of the warm-up period and ended at the completion of the cool-down period.

The rating of perceived exertion (RPE) has been used to monitor exercise intensity for middle-aged adults when the HR response is blunted by HR-controlling medications[18] and for older adults (>60 years of age) during walking or treadmill or cycle ergometer exercise.[19–24] During maximal graded cycle ergometer exercise, older women (>70 years of age) were able to quantify their sense of effort very well by using the RPE (RPE-HR relationship, r=.95).[24] In another study,[23] the RPE was accurately used by a group of women (>70 years of age) to regulate exercise intensity during a training program.

Submaximal Exercise Protocol

The exercise protocol for this study was modified from the Young Men's Christian Association (YMCA) protocol.[25] Each of the 3 constant workload levels was lengthened from 3 to 4 minutes to allow more time for the older adults in the present study to reach steady-state HR and $\dot{V}O_2$ levels.[26] Warm-up and cool-down phases remained the same as those in the YMCA protocol.[25]

Subjects completed a practice exercise session on the NuStep prior to 2 exercise test sessions. During the practice session, subjects wore the $K4b^2$ unit and the Polar Vantage NV chest strap so that they could become familiar with the equipment, exercise protocol, and exercise motion and so that we could determine the workloads to be used for the 2 standardized exercise test sessions. Subjects were seated comfortably on the NuStep with a 5-degree knee bend at maximal leg extension and a 5-degree elbow bend at maximal arm extension. The seat position and arm length were noted so that we could standardize subject positioning during the exercise test sessions. Resting HR and BP values were obtained, and age-predicted maximal HR (HR_{max}) was calculated with the equation $208-(0.7\times\text{age})$.[27] A metronome provided audible cues for a rate of 60 arm and leg push-pull cycles per minute during exercise. Subjects also watched the stepping rate displayed on the NuStep LCD panel so that they could monitor and adjust their tempo of push-pull cycles.

During the practice session, subjects completed 2-minute bouts of exercise on the NuStep at progressively higher workloads (range=1–8) to determine their HR responses and RPE scores at each workload. At the highest workload attained, subjects completed 4 minutes of exercise without exceeding 75% of the age-predicted HR_{max} to confirm their ability to complete this level of exercise. At the end of the practice session, a workload was determined for each of the three 4-minute stages of exercise in preparation for the 2 exercise test sessions. The workload for stage 1 (workload 1) was the highest workload given an RPE of 3 by the subject. The stage 3 workload (workload 3) was the highest workload for which the subject could complete 4 minutes of exercise. The stage 2 workload (workload 2) was selected to represent a workload halfway between those selected for stages 1 and 3. For each subject, age-predicted HR_{max} calculations, seat position and arm length, and workload for each of the 3 stages of exercise from the practice session were transferred to day 1 and day 2 data collection sheets to standardize the exercise protocol and subject positioning for testing. Within 10 days of the practice session, subjects completed 2 standardized exercise test sessions at the selected workloads.

On day 1 of testing, subjects were seated in the standardized position and wore the K4b^2 unit and the Polar Vantage NV chest strap. Subjects completed a 3-minute warm-up period at workload 1, three 4-minute stages at the preselected incremental workloads, and a cool-down period at workload 1. Subjects were encouraged regularly to maintain a push-pull tempo of 60 cycles per minute and to use the stepping rate displayed on the NuStep LCD panel to monitor and adjust their tempo of push-pull cycles. Exercise termination criteria included volitional stopping, an inability to maintain a cadence of 60 cycles per minute, an HR in excess of 75% of the age-predicted HR_{max}, or any of the ACSM guidelines for stopping an exercise test.[14]

At the onset of the warm-up period, the K4b^2 was turned on for continuous data collection throughout the exercise protocol and the cool-down period for each subject. Data from the NuStep, including displayed HR, MET values, and watts, and subjects' reported RPE scores were manually recorded on a data collection sheet during testing. In the third and fourth minutes of an exercise stage, NuStep MET values and watts were recorded every 6 seconds. During testing, subjects provided an RPE score at the end of the second minute in each 4-minute exercise stage. Heart rate, as displayed on the NuStep LCD panel, was recorded for each minute of warm-up, exercise, and cool-down periods. For the cool-down period, subjects were instructed to exercise slowly for 5 minutes at workload 1. If the HR was greater than 5 beats above the resting HR after 5 minutes, then the cool-down period was extended. Blood pressure was recorded after the completion of the cool-down period for safety and as a measure of recovery. The same exercise protocol, equipment, and individualized positioning were used for subjects during day 2 testing.

Table 2.
Resting Values for Heart Rate, Blood Pressure, and Respiratory Exchange Ratio (N=18)

Variable	$\overline{X}$ (SD) on Day:	
	1	2
Heart rate (bpm)	69 (12)	70 (14)
Systolic blood pressure (mm Hg)	143 (17)	139 (18)
Diastolic blood pressure (mm Hg)	74 (9)	72 (9)
Respiratory exchange ratio	0.80 (0.10)	0.81 (0.10)

Data Analysis

Descriptive analyses were performed for subjects' age, body mass index, MMSE score, walking aids, duration of residency, chronic health conditions, and medications. Data reduction was required to generate single data points for K4b^2 and NuStep MET values and for NuStep watts and HR. The last 30 seconds of breath-by-breath K4b^2 $\dot{V}O_2$ data in the third and fourth minutes of each 4-minute exercise stage were analyzed to produce 2 $\dot{V}O_2$ values (milliliters of oxygen per kilogram per minute) per 4-minute exercise stage for each subject. The mean of these 2 $\dot{V}O_2$ values was used as the K4b^2 MET value (1 MET=$\dot{V}O_2$/3.5) per exercise stage. The RER values for the subjects were generated by the K4b^2 software following the completion of testing. The NuStep MET values and watts in the third and fourth minutes of exercise were averaged to produce one MET value and one watt value per 4-minute exercise stage. The HR value for each exercise stage was the average of the HR values in the third and fourth minutes.

To determine whether resting HR, BP, and RER values were different on day 1 and day 2, we performed 3 separate one-way repeated-measures analyses of variance (ANOVAs). Six separate one-way repeated-measures ANOVAs were performed to determine whether watts, HR, percentage of HR_{max} (%HR_{max}) achieved, RPE, K4b^2 MET values, and NuStep MET values by exercise stage were different on day 1 and day 2. To investigate whether watts, HR, %HR_{max} achieved, RPE, K4b^2 MET values, and NuStep MET values collected on day 1 across the three 4-minute stages of exercise were different from those collected on day 2, we performed 6 separate 2-way repeated-measures ANOVAs. A Tukey *post hoc* test was used to identify the location of specific differences when the ANOVA omnibus F statistic was significant.

The relationship between group mean MET values from the K4b^2 and those from the NuStep for each 4-minute exercise stage was determined by use of Pearson *r* correlation coefficients on day 1 and day 2. The strength of the correlation was characterized as described by Colton[28]: 0 to .25=no relationship, .25 to .50=fair, .50 to .75=moderate to good, and greater than .75=very good to excellent.

The test-retest reliability of NuStep MET values, K4b^2 MET values, HR, and RPE was determined by use of intraclass correlation coefficients (ICC [2,1]) calculated from the results of the separate 2-way repeated-measures ANOVAs. The ICCs were characterized as described by Vincent,[29] who suggested that ICCs below .80 are of questionable importance for physiological data, whereas

Table 3.
Watts, Heart Rate, Percentage of Age-Predicted Maximal Heart Rate (%HR_{max}) Achieved, and Rating of Perceived Exertion at 3 Levels of Submaximal Exercise on 2 Test Occasions (N=18)

NuStep Workload, $\overline{X}$ (Range)[a]	Stage	Group $\overline{X}$ (SD) on Indicated Day for:							
		Watts		Heart Rate (bpm)		Age-Predicted %HR_{max} Achieved		Rating of Perceived Exertion	
		1	2	1	2	1	2	1	2
3 (1–5)	1	36 (12)	34 (12)	81 (13)	80 (14)	54 (8)	53 (9)	3 (1)	4 (1)
4 (2–7)	2	39 (13)[b]	39 (14)[b]	85 (14)[b]	84 (15)[b]	56 (9)[b]	56 (10)[b]	4 (1)[b]	5 (1)[b]
5 (3–8)	3	44 (14)[c]	44 (15)[c]	92 (14)[c]	90 (15)[c]	61 (10)[c]	60 (10)[c]	6 (1)[c]	6 (1)[c]

[a] For each workload, SD=1.
[b] Significant difference (P<.05) between stage 1 and stage 2.
[c] Significant difference (P<.05) between stage 1 and stage 3 and between stage 2 and stage 3.

Table 4.
Reliability and Validity of NuStep and $K4b^2$ Values for Metabolic Equivalents of Task (MET Values) at 3 Exercise Stages on Day 1 and Day 2 of Testing (N=18)[a]

NuStep Workload, $\overline{X}$ (Range)[b]	Stage	Reliability of:						Validity (Pearson r Correlation Coefficient) of NuStep vs $K4b^2$ MET Values on Day:	
		NuStep			$K4b^2$				
		MET Values on Day:		ICC (2,1) (95% CI)	MET Values on Day:		ICC (2,1) (95% CI)	1	2
		1	2		1	2			
3 (1–5)	1	2.20 (0.37)	2.19 (0.32)	.89 (.73–.96)	2.30 (0.37)	2.25 (0.39)	.85 (.65–.93)	.97	.86
4 (2–7)	2	2.36 (0.39)[c]	2.35 (0.38)[c]	.99 (.97–1.00)	2.56 (0.46)[c]	2.46 (0.47)[c]	.87 (.71–.94)	.89	.85
5 (3–8)	3	2.55 (0.44)[d]	2.54 (0.42)[d]	.99 (.97–1.00)	2.78 (0.52)[d]	2.64 (0.51)[d]	.88 (.73–.95)	.92	.87

[a] MET values are expressed as group mean (SD). ICC=intraclass correlation coefficient, 95% CI=95% confidence interval of the mean. Pearson r correlation coefficients represent the association between NuStep and $K4b^2$ MET values by exercise stage on day 1 and day 2 of testing.
[b] For each workload, SD=1.
[c] Significant difference (P<.05) between stage 1 and stage 2.
[d] Significant difference (P<.05) between stage 1 and stage 3 and between stage 2 and stage 3.

values of .80 to .89 reflect moderate reliability and values greater than .90 indicate high reliability.

Data were analyzed by use of SPSS-PC (version 15.0).[#] The level of significance was set at P<.05 for all statistical tests.

Results

Data Obtained at Rest

No significant differences were found between day 1 and day 2 resting HR, BP, and RER values (Tab. 2)

[#] SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Exercise Test Data

Watts, HR, %HR_{max}, and RPE (Tab. 3) and $K4b^2$ MET values and NuStep MET values (Tab. 4) by exercise stage were not significantly different on day 1 and day 2. Significant differences in exercise responses (Tabs. 3 and 4) were found between the stages of exercise (stage 1 versus stage 2, stage 1 versus stage 3, and stage 2 versus stage 3). These differences in exercise responses with increasing workloads across stages were found for both day 1 and day 2 of testing. Between stages 1 and 2, watts, HR, %HR_{max}, and RPE (Tab. 3) and $K4b^2$ MET values and NuStep MET values (Tab. 4) were different on day 1 (P<.0001–P=.002) and day 2 (P<.0001–P=.018). Furthermore, watts, HR, %HR_{max}, and RPE (Tab. 3) and $K4b^2$ MET values and NuStep MET values (Tab. 4) were different between stages 1 and 3 (P<.0001) and between stages 2 and 3 (P=.001–P=.022).

Concurrent Validity of NuStep MET Values

Pearson r correlation coefficients for NuStep and $K4b^2$ MET values at each of the 3 stages of exercise ranged from very good to excellent on both day 1 (r=.97, .89, and .92) and day 2 (r=.86, .85, and .87) (Tab. 4). Bland-Altman[30] plots were constructed to provide a visual representation of systematic bias and variability.[30] In these plots, subjects' averaged K4b^2 and NuStep MET values were plotted against the difference score for their K4b^2 and NuStep MET values collected during the third and fourth minutes of an exercise stage. For day 1, there appeared to be a tendency for the K4b^2 to measure higher MET values compared with the NuStep (Fig. 2). For day 2, the spread of scores around the zero point suggested the error was unbiased (Fig. 3). Bland-Altman plots for each exercise stage are shown in Figure 2 for day 1 and Figure 3 for day 2.

Test-Retest Reliability of Exercise Responses in Older Adults

The test-retest reliability of HR responses for the study subjects at each exercise stage was moderate to high: ICC (2,1)=.87, .91, and .89. The data also showed moderate to high reliability of $\dot{V}O_2$, or K4b^2 MET values, across the 3 stages of exercise (Tab. 4). In addition, RPE scores reported by subjects at stages 1, 2, and 3 of exercise were moderate to high: ICC (2,1)=.88, .87, and .93, respectively.

Discussion

The main findings of our study were that the software-generated NuStep MET values, or indirect measures of $\dot{V}O_2$, were not different from the directly measured K4b^2 MET values during submaximal exercise in our sample of frail older adults living in long-term care centers and that this group of older adults with multisystem impairments showed reproducible exercise responses (HR and K4b^2 MET values) during 2 test sessions with a standardized submaximal 3-stage exercise protocol. These results are important for physical therapists and rehabilitation profes-

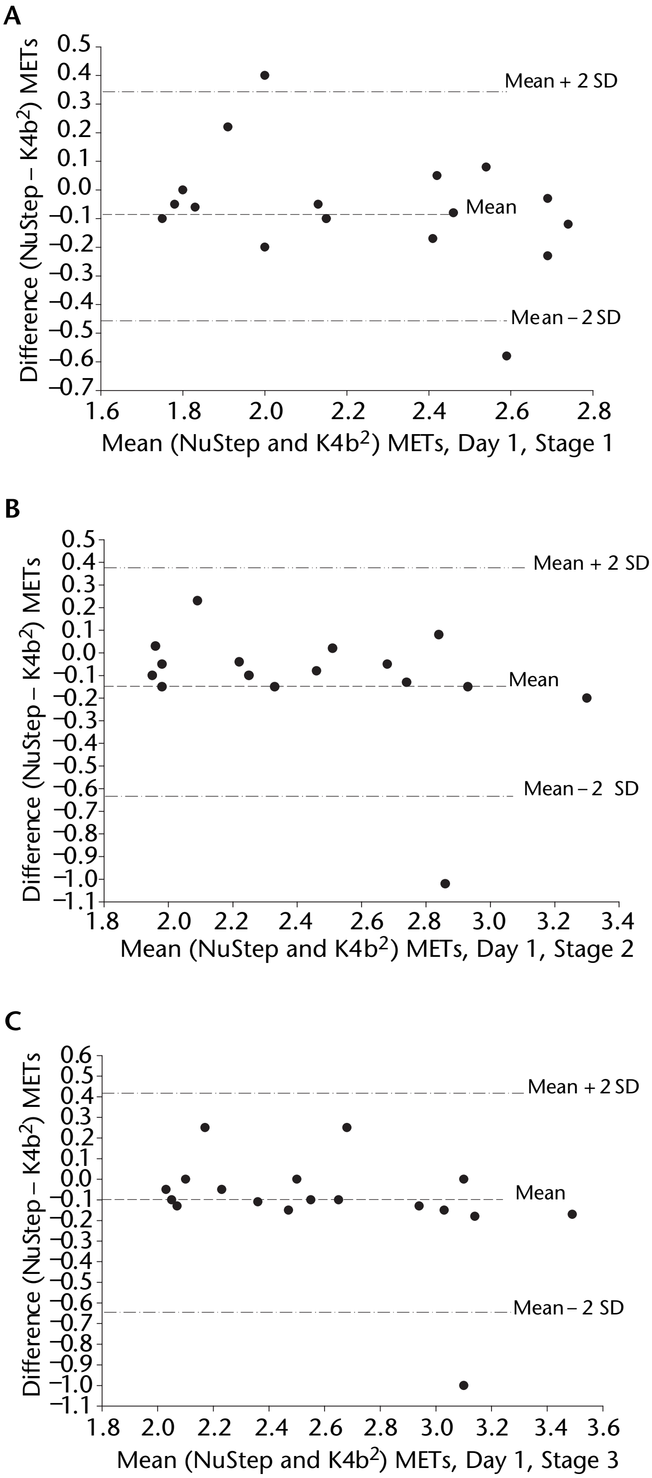

Figure 2.
Bland-Altman plots of day 1 NuStep and K4b^2 metabolic equivalents of task (METs) for stage 1 (A), stage 2 (B), and stage 3 (C) (N=18). Upper and lower 95% limits of agreement are shown.

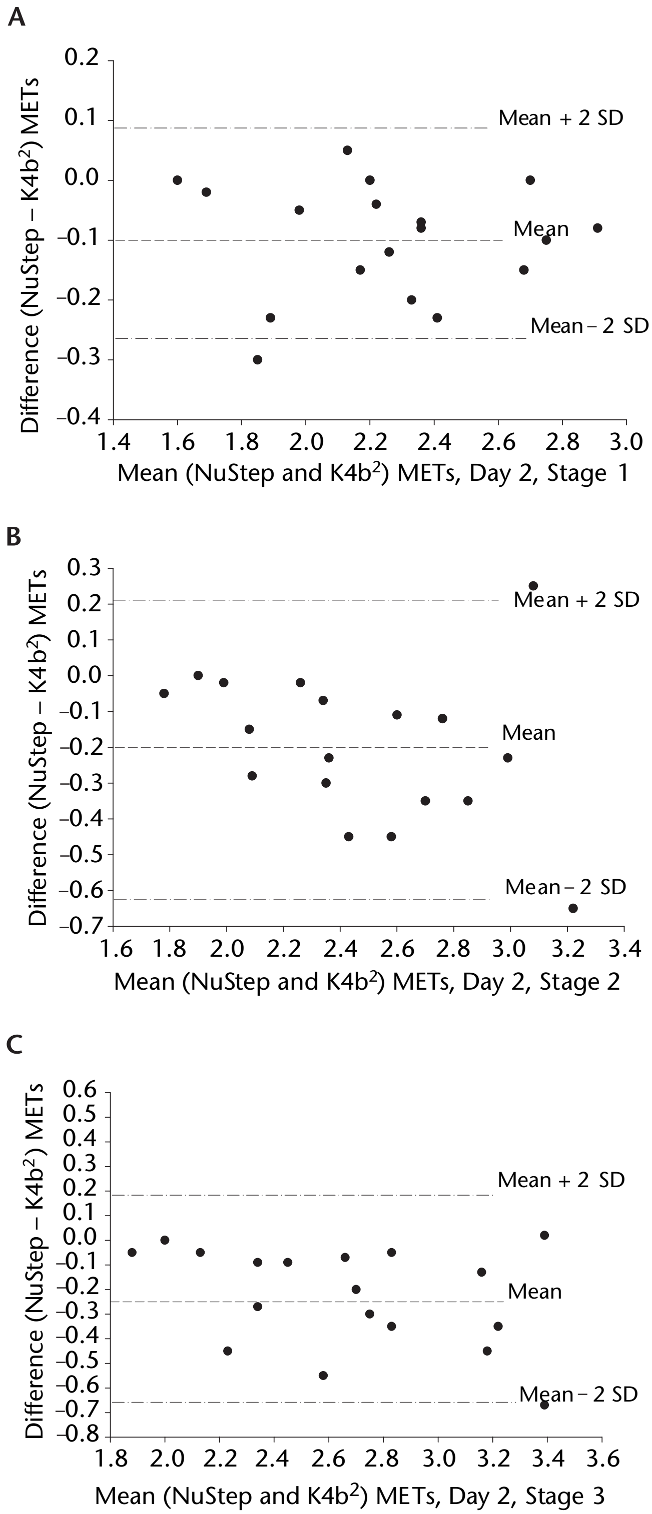

Figure 3.
Bland-Altman plots of day 2 NuStep and $K4b^2$ metabolic equivalents of task (METs) for stage 1 (A), stage 2 (B), and stage 3 (C) (N=18). Upper and lower 95% limits of agreement are shown.

sionals using the NuStep to assess submaximal aerobic performance and to monitor and prescribe exercise training. Also of clinical importance is that because the NuStep is ergonomically designed and has a range of workload levels to accommodate a broad range of people with variations in height, weight, range of motion, and strength and mobility impairments, no equipment modifications were necessary to enable our group of older adults with multiple health conditions to complete submaximal all-extremity exercise at some workload.

A limitation of the present study was that the complete range of available workloads was not tested. Our subjects exercised up to a mean workload of 5 (range=3–8) out of 10 workloads. The group mean age-predicted $\%HR_{max}$ achieved at the highest workload tested was 61% (SD=10%). Only 1 of our 18 subjects was tested at workload 8, possibly because of low levels of aerobic fitness, higher ratings of perceived exertion secondary to a lack of regular aerobic exercise, the cumulative effects of multiple chronic conditions, and the presence in many subjects of chronic cardiovascular conditions (78% of subjects were prescribed β-blockers). Future studies addressing the reliability and validity of exercise responses in older adults at higher NuStep workload levels will need to recruit older subjects with higher functional abilities.

The combined contribution of arms and legs to work output during exercise on the NuStep facilitated exercise participation in our group of older adults with multisystem impairments. Similarly, given that the HR could not be relied on solely to reflect exercise intensity because most subjects were taking β-blockers, the RPE provided a mode for monitoring subjects during exercise and for guiding the choice of workloads.

The RPE provided by exercising older adults was shown to be a reliable measure of exercise intensity, with moderate to high ICCs.

Although no randomized clinical trials have examined the therapeutic effects of all-extremity exercise, 2 studies supported the use of combined upper- and lower-limb exercises.[31,32] Loudon et al[31] compared peak $\dot{V}O_2$ values from maximal treadmill and all-extremity ergometer (Pro II Power Trainer**) tests in women aged 30 to 60 years who were healthy and found that all-extremity exercise was a reliable and valid mode of testing aerobic fitness and a viable alternative to using a treadmill. Hill et al[32] demonstrated that the all-extremity Power Trainer safely measured cardiopulmonary fitness in people with movement impairments following a stroke. Finally, Zehr[33] suggested that rhythmic movements of the upper and lower limbs on the NuStep during supported sitting elicited neural responses similar to those elicited by walking, and Ferris et al[34] reported that rhythmic upper-limb movements resulted in increased lower-limb muscle recruitment, which may benefit people with impairments of the lower or upper limbs or both. These preliminary findings, combined with our results, suggest that all-extremity semirecumbent exercise machines may be a viable exercise option for older adults and other people with health and functional impairments.

Conclusion

Software-generated NuStep MET values were shown to be valid compared with K4b[2] direct physiological measurements of $\dot{V}O_2$. The exercise responses of frail older adults were reliable across the range of workloads tested in the present study, suggesting that direct physiological assessments are not needed for monitoring subjects when the NuStep is used for exercise testing or training. The present study, therefore, provides preliminary evidence to support the use of the NuStep all-extremity semirecumbent exercise machine for aerobic exercise by older adults who have multiple health conditions and who have difficulty with traditional exercise modalities. The results of this study are important for physical therapists and rehabilitation professionals in hospitals and long-term care centers using these exercise machines to maintain or improve quality of life for frail older adults.

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Dr Mendelsohn, Dr Connelly, and Dr Overend provided concept/idea/research design. Dr Mendelsohn and Dr Connelly provided data collection and analysis and project management. Dr Connelly, Dr Overend, and Dr Petrella provided facilities/equipment. Dr Connelly and Dr Petrella provided institutional liaisons. All authors provided writing and consultation (including review of manuscript before submission). Special thanks are due to the study volunteers and staff at Mount Hope Centre for Long Term Care and Veterans Care at Parkwood Hospital, St Joseph's Health Care London.

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