Wrist-worn Fitness Trackers and their Application to the Wheelchair Bound Population.

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Abstract

Many consumer available wrist worn fitness devices have developed the ability to estimate peak oxygen consumption values. However, the accuracy of these estimates have not been widely studied in their application to the wheelchair bound population. The purpose of this study aimed to evaluate the accuracy of wrist-worn fitness devices in quantifying heart rate, energy expenditure, and VO_{2peak} pertaining to the wheelchair bound population. Thirteen (30.08 ± 10.78 yr) healthy males (n = 6) and females (n = 7) were outfitted with three different wrist-worn fitness devices simultaneously for the entirety of a 7-day protocol which included two in person testing sessions. The monitors included the Garmin Fenix 5 and Huawei Band 3 worn on the left wrist, and the Apple Watch series 4 worn on the right wrist. The accuracy of heart rate capture, energy expenditure, and VO2peak estimates were evaluated relative to the criterion values obtained from a laboratory metabolic analysis system (Parvo Medics True-one 2400) to include a Polar heart rate monitor. Differences from criterion measures were expressed as a mean absolute percent error and were evaluated using 95% equivalence testing. For the overall group comparisons, the mean absolute percent error values pertaining to estimated peak oxygen consumption (computed as the average absolute value of the group-level errors) were 48.03%, 50.42%, and 58.44% for the Huawei Band 3, Apple Watch 4, and Garmin Fenix 5 respectively. The strongest relationship observed between the metabolic cart and the monitors gathering VO_{2peak} estimates were seen for the Apple watch (r= 0.772) and the Garmin Fenix 5 (r= 0.715). The strongest relationship observed between the Polar device and all other monitors gathering heart rate estimates were seen for the Apple Watch (r= 0.870) and the Garmin Fenix 5 (r= 0.843). The indicators of agreement clearly indicated that none of the devices were in agreement with the criterion measure for peak oxygen consumption. Inter-device correlations for heart rate monitoring during the laboratory testing session were moderately significant.

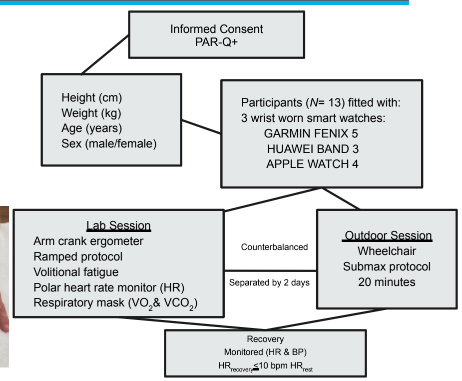
Introduction

The Center for Disease Control and Prevention (CDC) suggested that 1 in 4 adults in the United States (US), or nearly 61 million Americans, currently live with a disability that impacts major portions of their life (CDC, 2018). Moreover, 1 in 7 US adults live with severe mobility deficits that require mobility assistive devices. A study into Healthy People 2010 by the CDC indicated that people with major disabilities are prone to less physical activity participation than that of the general population. Of the wheelchair bound population, only 13-16% report regular physical activity (Hiremath & Ding, 2011). Regardless of the population, a lack of physical activity is associated with decreased muscular strength and endurance, flexibility, and aerobic capacity (Hiremath & Ding, 2011). As suggested by Hiremath & Ding (2011), one effective way to promote physical activity in wheelchair bound populations is to provide an estimate of biometric measures and daily energy expenditure analysis through the implementation of fitness devices.

Peak oxygen consumption has long been the accepted measure for cardiorespiratory fitness (Orr et al., 2013; Price et al., 1997). However, due to the inherent recruitment of smaller muscle groups in upper extremity exercise, peak oxygen consumption values can be drastically reduced. Orr and associates (2013) determined that arm ergometry elicited peak VO2 values at a 34% reduction when compared to lower extremity exercise. This reduction in oxygen consumption can produce complications when wrist-worn fitness devices are utilized by the wheelchair bound population. Therefore, the purpose of the current study was to evaluate the accuracy of wrist-worn fitness devices in quantifying heart rate, energy expenditure, and VO2 peak pertaining to the wheelchair bound population. It was hypothesized that all devices would accurately estimate VO_{2peak} for upper extremity exercise.

Methods

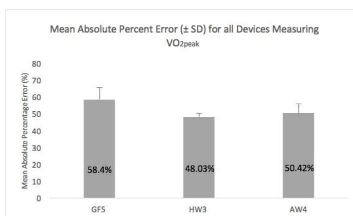
- Quantitative correlational design
- Subjects (N = 13)
  - 7 Female
  - 6 Male
- 7 day protocol
- 2 individual exercise sessions
- 2 testing sessions



Results

Table 1. Physical chacteristics of male (n = 6) and female (n = 7) subjects (N = 13).

	Male		Female	
	Mean (SD)	Range	Mean SD	Range
Age (yr)	35 (10.68)	21-47	25.86 (9.62)	18-46
Height (cm)	179 (4.69)	173.5-185.5	166.14 (3.39)	162-170
Weight (kg)	84.01 (13.60)	69.5-105.45	67.40 (12.95)	52.7-88.6



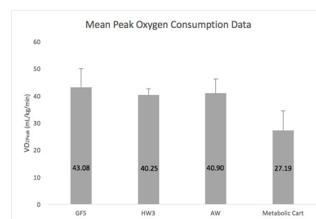


Table 2. VO2Peak correlation matrix.

	Metabolic Cart	GF5	HW3	AW
Metabolic Cart	1	0.72**	0.17	0.77*
GF5		1	0.37	0.56
HW3			1	-0.34
AW4				1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 3. LT heart rate correlation matrix.

	Polar	AW	HW3	GF5	Interval
Polar	1.00	0.87**	0.64	0.84**	0.72
AW4		1.00	0.70	0.88**	0.78*
HW3			1.00	0.78*	0.71
GF5				1.00	0.71
Interval					1.00

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Discussion

The results displayed unfavorable outcomes for the estimation of VO_{2peak} obtained during exclusive upper body exercise in all devices. However, estimates for heart rate were more correlated during the laboratory session. With the exception of the Huawei Band 3, the devices were highly correlated with the criterion measure produced by Polar heart rate capture.

While examining VO_{2peak} estimates produced by the devices during upper extremity exercise, it was observed that each device overestimated the measure by at least 48%. Orr and associates (2013) determined that oxygen consumption during upper extremity exercise were significantly less than that of cycling. This is due to the recruitment of small musculature during upper extremity exercise. In addition, the oxidative capacity of upper extremity musculature is limited due to early oxygen utilization.

Heart rate correlations, both in the field session and laboratory session, were variable at best. All three devices (AW, GF5, and HW3) displayed moderate correlations during the field test. However, higher inter-device and device to criterion correlations were noted during the laboratory test (AW r= 0.870; GF5 r= 0.843; HW3 r= 0.642). Studies completed by Evenson and associates (2015) and Topoj and associates (2018) both found that wrist-worn fitness devices displayed more linear reliability in the areas of heart rate, step count, and energy expenditure as intensity increases. This could also explain the disparity between heart rate reliability between the field and laboratory sessions as participants were given a target intensity zone to maintain while in the wheelchair (FT) portion of the testing, while a ramped protocol was instituted during the arm ergometer (LT) portion of the test.

Inter-device energy expenditure correlations, both in the field session and laboratory session, were also variable. Moderate correlations were observed for all devices in both settings. Due to the fact that the primary mode for energy expenditure calculations is heart rate capture, it would seem appropriate that energy expenditure estimates would vary when heart rate varies such as in the current study. Ainslie and associates (2003) determined that physical activity estimates from heart rate can be drastically improved when used in conjunction with devices such as pedometers and accelerometers. However, when presented with horizontal motion capture, such as that in wheelchair ergometry and arm ergometry, estimates seem to become skewed due to the fact that typical algorithms for calculating these estimates are based on the vertical motion capture as with that of the general ambulatory population.

This study aimed to provide new insights about consumer based wrist-worn fitness devices and their application to the wheelchair bound population, but it does have some limitations. The sample population, while containing a wide age range and including both genders, only included healthy individuals who were part of the able bodied population. Therefore, application for the wheelchair bound population was only by extrapolation. Another limitation involved the location of device wear for the entirety of the protocol. Due to time constraints, participants were asked to wear all three devices at the same time (GF5 and HW3 on left wrist; AW on right wrist). Although this allows for a more expedient time frame, it is not consistent with the manufacturers' suggested location of wear. Future studies should incorporate similar protocols while testing one device at a time.

It is unreasonable to expect consumer based monitors to match the utility of other laboratory grade devices because they are developed for a wide range of individuals and with cost constraints. However, it is important for researchers, fitness professionals, health professionals, and target populations to be aware of the relative accuracy of various devices so that it can be factored into decisions when selecting devices. It is important to note that results did indicate increased reliability for heart

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