International Journal of EXERCISE SCIENCE

Original Research

Reliability of the Polar T31 Uncoded Heart Rate Monitor in Free Motion and Treadmill Activities

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ABSTRACT

International Journal of Exercise Science 12(4): 69-76, 2019. The Polar T31 uncoded heart rate monitor (T31) is currently accepted as a precision measurement device that can be used in lieu of electrocardiography. However, minimal literature exists to verify reliability when used for this purpose. The purpose of this study is to evaluate the reliability of heart rate (HR) measurements obtained from the T31. Forty volunteers participated in a three-day test-retest protocol. Participants gave anthropometric data on the first day. On the second day, they performed two 5-minute self-paced free motion walks (FMW) and two 5-minute self-paced free motion jogs (FMJ). Finally, on the third day, they performed two 5-minute treadmill walks (TW) and two 5-minute treadmill jogs (TJ). Treadmill speeds for each TW and TJ were determined by the distances traveled during the FMWs and FMJs on day 2. HR values at rest (HRR) and while in motion (minutes 1-5) were evaluated (HRM). Values calculated used Cronbach's α ($\geq$0.70) for reliability with significance accepted at $p<0.05$. FMW HRR (all, α=0.96; male, α=0.97; female, α=0.94), FMJ HRR (all, α=0.98; male, α=0.98; female, α=0.99), TW HRR (all, α=0.96; male; α=0.92; female, α=0.98), TJ HRR (all, α=0.97; male, α=0.98; female, α=0.96), FMW HRM (all, α=0.93; male, α=0.93; female, α=0.91), FMJ HRM (all, α=0.93; male, α=0.94; female, α=0.90), TW HRM (all, α=0.95; male, α=0.92; female, α=0.95), TJ HRM (all, α=0.94; male, α=0.95; female, α=0.92). All p-values < 0.001. The T31 provided reliable measures at rest and for walking and jogging in both a free motion and treadmill setting.

KEY WORDS: Test-retest, wearable technology, fitness

INTRODUCTION

The Polar T31 uncoded chest worn heart rate monitor (T31; Lake Success, NY, USA) is generally accepted as a precision heart rate (HR) measurement device. Many studies have utilized it for exercise evaluation purposes (6, 19), occupational applications (9, 35), medical research (31, 32), and for validating alternate heart rate monitors (4, 20, 21, 28). While the use of the T31 is common, the question remains whether it is a viable substitute for an electrocardiograph instrument (ECG). The ECG is the gold standard by which HR measurements are compared (16, 22, 37, 40). While considered the gold standard for laboratory use, ECGs are not feasible in all locations due to size, financial cost, or availability of trained personnel. For an alternate heart rate monitor to be used in lieu, certain criteria need to be established. First, it must measure what it claims to measure within an acceptable range. Second, it must be consistent. Third, it must be financially reasonable, and fourth, it needs to be user friendly. Finally, its use should minimally alter the behavior of the user as to not influence its measurement (23). Because the T31 is smaller, more cost effective, portable, and user friendly when compared to an ECG system, it has become the typically acceptable method for measuring HR when an ECG is not an option.

While the T31 is commonly used by investigators in many areas of study, there is only one known study that has assessed its accuracy. Bouts et al. compared the HR measured by a T31 and an ECG for 15 exercising individuals (4). The HR at nine different intensities of stationary cycling were compared. The Pearson's Product Moment Correlation (r) between the two ranged from 0.976 to 1.00 with all p values < 0.05. While this comparison showed that the T31 can be considered accurate, to our knowledge no known research has shown that it is consistent in its measurements.

The purpose of this study was to determine if the T31 HR values could be considered reliable at rest (HRR) and during subsequent motion-based activities (HRM). We hypothesized that the T31 would be reliable for both HRR and HRM in free motion and treadmill activities for both the male and female genders.

METHODS

Participants

Young (N=40, male n=20, female n=20), healthy (identified as low risk according to the ACSM pre-participation screening questionnaire), individuals volunteered for this investigation (descriptive characteristics are provided in Table 1). Participants filled out an informed consent form that was approved by the institutional review board (#885569-3).

Table 1. Participants characteristics.

	Age (yrs)	Height (cm)	Mass (kg)	BMI (kg/m^2)
All participants	25.09±7.17	169.64±11.18	77.19±19.2	26.43±5.19
Male participants	24.46±3.07	176.47±8.32	83.56±15.02	26.27±4.26
Female participants	25.72±5.76	162.81±6.25	70.82±12.51	26.59±4.13

BMI = Body Mass Index

Protocol

On day one, participants reported to the University of Nevada, Las Vegas Exercise Physiology Lab (UEPL) and provided anthropometric data. Participant age (years) was self-reported, height (cm) was measured with a Health-o-meter wall mounted height rod (Pelstar LLC/Health-o-meter, McCook, IL), mass (kg) and Body Mass Index (BMI) was provided by a hand-and-foot bioelectric impedance analyzer (seca mBCA 514 Medical Body Composition Analyzer, Seca North America, Chino, CA).

On day two, participants were fitted with a T31 and a Polar CE0537 watch (PW) (Lake Success, NY). They then reported to a 200-foot section of building hallway that was marked off with cones. After a 5-minute seated rest period, HRR was recorded. Participants then completed the first 5-minute self-paced free motion walk (FMW-1) back and forth between the cones with HRM recorded every minute until completion. Following a 5-minute seated rest period, HRR was recorded and subjects then completed the first 5-minute self-paced free motion jog (FMJ-1) with HRM again being recorded every minute. Participants rested in a seated position for 10-minutes. They then performed a second self-paced 5-minute free motion walk (FMW-2) and jog (FMJ-2) with HRR and HRM recorded in the same manner. Distance traveled for FMW-1, FMW-2, FMJ-1, and FMJ-2 was measured. Speed in meters per minute ($m \bullet min^{-1}$) was calculated and rounded to the nearest 0.1 for all four conditions (miles per hour; [mph] noted after).

On day three, participants reported to the UEPL for treadmill-based walking and jogging. Both were performed on a Trackmaster treadmill (Full Vision, Inc. Newton, KS). Participants were again fitted with a T31 and PW. After a 5-minute seated rest period, HRR was recorded. They then completed the first 5-minute treadmill walk (TW-1) at the speed calculated from FMW-1. HRM was recorded every minute until completion. Following a 5-minute seated rest period, HRR was recorded and subjects then completed the first 5-minute treadmill jog (TJ-1) at the speed calculated from FMJ-1. HRM was again recorded every minute. Participants then rested in a seated position for 10-minutes. They then performed a second 5-minute treadmill walk (TW-2) and jog (TJ-2) with HRR and HRM recorded in the same manner as the first treadmill activities. Speeds for TW-2 and TJ-2 were calculated from FMW-2 and FMJ-2. The grade for all treadmill testing was set to 0%.

Statistical Analysis

Test-retest reliability was determined through Cronbach's α using the Intraclass Correlation function in IBM SPSS (IBM Statistics version 24.0, Armonk, NY). Significance was accepted at the $p < 0.05$ level and considered to have acceptable reliability when ICC > 0.70. β was set at 0.80. Effect size was calculated using G*Power statistical software (G*Power version 3.1.9.2, Universität Kiel, Kiel, Germany). At the time of this study, there was no previous research data to calculate an "*n*" size. However, using the indicated α, β, and actual "*n*", the calculated effect size for HR was 0.40.

RESULTS

When walking or jogging in either a free motion or treadmill setting was evaluated, all measurements were observed to have significant test-retest reliability and met the minimum threshold with HRR ranging from 0.92 to 0.98 (see Table 2) and HRM (minutes 1-5) ranging from 0.90 to 0.95 (see Table 3).

Table 2. Heart rate at rest test-retest values.

		HRR 1	HRR2	Cronbach's α	*p*-value
All	FMW	92±15	95±15	0.96	<0.001
	FMJ	94±17	97±17	0.98	<0.001
	TW	88±13	92±14	0.96	<0.001
	TJ	98±16	101±16	0.97	<0.001
Male	FMW	87±15	90±16	0.97	<0.001
	FMJ	89±16	91±15	0.98	<0.001
	TW	83±9	86±11	0.92	<0.001
	TJ	95±15	97±14	0.98	<0.001
Female	FMW	97±14	100±13	0.94	<0.001
	FMJ	100±16	105±16	0.99	<0.001
	TW	94±14	99±14	0.98	<0.001
	TJ	102±17	105±17	0.96	<0.001

HRR = Heart Rate at Rest, FMW = Free Motion Walk, FMJ = Free Motion Jog, TW = Treadmill Walk, TJ = Treadmill Jog

Table 3. Heart rate while moving test-retest values. Minutes 1-5

		HRM 1	Average Speed (1st) m•min^{-1} [mph]	HRM 2	Average Speed (2nd) m•min^{-1} [mph]	Cronbach's α	*p*-value
All	FMW	109±16	74.6±6.6 [2.8±0.2]	115±17	75.6±7.0 [2.8±0.3]	0.93	<0.001
	FMJ	156±15	130.0±17.7 [4.9±0.7]	160±14	130.9±19.6 [4.9±0.7]	0.93	<0.001
	TW	107±16	74.6±6.6 [2.8±0.2][1]	115±17	75.6±7.0 [2.8±0.3][3]	0.95	<0.001
	TJ	151±17	130.0±17.7 [4.9±0.7][2]	160±14	130.9±19.6 [4.9±0.7][4]	0.94	<0.001
Male	FMW	102±14	73.8±7.1 [2.8±0.3]	108±16	75.2±7.6 [2.8±0.3]	0.93	<0.001
	FMJ	153±15	128.0±15.9 [4.8±0.6]	158±15	128.9±17.5 [4.8±0.7]	0.94	<0.001
	TW	102±12	73.8±7.1 [2.8±0.3][1]	108±16	75.2±7.6 [2.8±0.3][3]	0.92	<0.001
	TJ	145±17	128.0±15.9 [4.8±0.6][2]	158±15	128.9±17.5 [4.8±0.7][4]	0.95	<0.001
Female	FMW	116±14	75.3±5.9 [2.8±0.2]	122±16	76.1±6.3 [2.8±0.2]	0.91	<0.001
	FMJ	159±13	132±19.5 [4.9±0.7]	163±13	132.8±21.5 [5.0±0.8]	0.90	<0.001
	TW	113±18	75.3±5.9 [2.8±0.2][1]	122±16	76.1±6.3 [2.8±0.2][3]	0.95	<0.001
	TJ	157±16	132±19.5 [4.9±0.7][2]	163±13	132.8±21.5 [5.0±0.8][4]	0.92	<0.001

HRM = Heart Rate in Motion, FMW = Free Motion Walk, FMJ = Free Motion Jog, TW = Treadmill Walk, TJ = Treadmill Jog. 1. Treadmill walking speed 1 based on the corresponding free motion speed from the first walk. 2. Treadmill jogging speed 2 based on the corresponding free motion speed from the first jog. 3. Treadmill walking speed 1 based on the corresponding free motion speed from the second walk. 4. Treadmill jogging speed 2 based on the corresponding free motion speed from the second jog.

DISCUSSION

The primary aim of this study was to examine the reliability of the T31 to measure HR at rest and while performing various activities in different settings. It is the first to demonstrate that the T31 is reliable when used by the general population under conditions such as walking and jogging, in both a free motion and treadmill setting. When evaluating all participants, the lowest HRR result was α=0.96 and lowest HRM was α=0.93. However, there are different physical characteristics when comparing males and females. On average, males weigh about

15% more than females and are taller by about 15cm (29). Male skeletons are also generally more massive and wider than females, especially in the rib cage (8). Because the T31 is worn on the sternum, measurements taken on a male may have been affected by these larger anatomical proportions. It was important to categorize our analysis by sex to account for these variances. Even when reliability was separated out to account for sex, we observed the lowest HRR for males and females to be $\alpha=0.92$ and $\alpha=0.94$ respectively. The lowest HRM for males and females was $\alpha=0.92$ and $\alpha=0.90$ respectively. We believe this study provides strong evidence that the reliability of the T31 is excellent for use by all.

To date, four manuscripts in 2018 utilizing the Polar T31 monitor are available through PubMed and the National Library of Medicine search, and 336 hits on articles in 2018 were found using Google Scholar. Previous research includes numerous studies involving the measurement of HR with a T31 for a multitude of purposes including human physiological research (2, 7, 13, 41), occupational related applications (12, 14, 24, 36), fitness assessment (1, 5, 17, 25), athlete evaluation (3, 15, 26, 30), setting exercise intensity (11, 27, 33, 34), and validation of alternate HR instruments (10, 18, 38). The popularity and use of the T31 make the results of the current investigation both timely and necessary.

While it is widely accepted as a precision measurement device for HR, we are aware of no other research, except for Bouts et al., that has reported on the validity or reliability of the T31 (4). As an ECG system is costly and requires some training to operate, the use of an acceptable substitute that is cost efficient, user-friendly, and easily purchased can be straightforwardly argued as desirable by those that do not have access to an ECG system. The T31 is lightweight, water-resistant, slender, and comes with a medium strap designed to fit chest sizes from 63.5cm to 137 cm (25" to 54"). It currently retails for $39.95 (39). It is for these reasons that it had become one of the preferred alternates for the ECG.

The lack of published literature regarding the specific accuracy and consistency of the T31 is evident when scientific reference searches are performed. This is an important point since its use is widespread in many areas of research. Therefore, it was viewed as imperative by the authors to evaluate and report the current findings. This gives those that do use the T31 confidence based on solid statistical analysis. In concert with the findings reported by Bouts et al. researchers can continue to use the T31 as it is both valid and reliable in returning heart rate measures (4).

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