Original Research Article

Changes in beat by beat heart rate slopes during six minute walk test among healthy adult Saudi male students

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International Archives of Integrated Medicine, Vol. 5, Issue 3, March, 2018.

Available online at http://iaimjournal.com/
ISSN: 2394-0026 (P) **ISSN: 2394-0034 (O)**
Received on: 07-02-2018 **Accepted on:** 17-02-2018
Source of support: Nil **Conflict of interest:** None declared.
How to cite this article: Muath Aleid. Changes in beat by beat heart rate slopes during six minute walk test among healthy adult Saudi male students. IAIM, 2018; 5(3): 60-70.

Abstract

Clinically, six minute walk test (6MWT) is the most common exercise test. It is used to estimate the level of physical fitness among patients. The aim of this research to measure the beat by beat heart rate slopes instead of depending on the covered distance to predicate and estimate the level of physical fitness during 6MWT. Seventy (70) healthy adult male students aged between 18 to 27 years were recruited randomly from the general Saudi population in Riyadh. 6 MWT using 50 meter corridor was performed according to standardized American Thoracic Society (ATS) guidelines. Mean distance walked in 6 minutes (470.5±64.6 meters) and beat by beat heart rate (HR) was calculated by heart rate monitor. In addition Body mass index (BMI), Body surface area (BSA), Borg Rating of Perceived Exertion (BRPE) and Maximum predicted heart rate percentage (MPHRP) was also calculated. A stepwise regression equation was used to predict six minute walk test distance (6MWTD), six minute walk test slope (6MWTS) and recovery slope. There was a significant correlation between 6MWTS and the recovery slope ($r= -0.460$, $p < 0.001$), 6MWTS with 6MWTD ($r= 0.264$, $p<0.05$) and recovery slope with 6MWTD ($r= -0.249$, $p < 0.05$). In conclusion, both 6MWTS and recovery slope can predict the 6MWD.

Key words

Heart rate, Six minute walk test, Beat by beat heart rate slope.

Introduction

In many chronic conditions, physical activity could improve physical function, reduce symptoms, and enhance quality of life [1, 2] while the benefits of physical activity are well known. 6MWT is a clinical-based, sub maximal exercise test for functional capacity [3, 4]. The 6MWT is performed by instructing the participant to walk as fast as possible (without running) on a flat surface in 6 minutes, the distance walked (6MWD) is recorded [4]. 6MWD is a good predictor for morbidity and mortality in various diseases in adult populations [5-7].

The validity, reliability and responsiveness of the 6MWT has been studied in depth [8, 9]. A literature review of the 6MWT has revealed its potential to be a self-administered, home-based monitoring tool [10]. Due to the simple, safe and inexpensive nature of the 6MWT, it could be particularly useful in people with heart failure, as an exemplar of many other chronic diseases.

Traditionally, 6MWT has been used to assess disease severity [11, 12], progression, and response to treatment in patients with pulmonary arterial hypertension [13-15].

Previously, studies have been conducted reporting normal values for 6 min walk distance in the similar age groups amongst Chinese, Caucasian and UK children [16-18].

In recent years, investigators have focused on parameters other than the 6-min walk distance to enhance the information obtained from this simple, safe, and inexpensive examination that is representative of daily life activities [19].

Adriano R. Tonell, et al. [19] obtained real-time beat-by-beat heart rate (HR) acceleration and decay slopes during the 6-meter walk test in different patients with pulmonary arterial hypertension (PAH), other lung diseases, and healthy controls using a portable impedance cardiograph, They hypothesized that the slopes of the HR increase and decrease during the activity and recovery phase of the 6MWT will be different among three groups and there will be a difference in the acceleration and decay HR slopes of patients with PAH or other lung diseases who experience disease progression during their follow-up.

Many studies on functional walking tests concluded that the 6-min walk test is easier to carry out, more acceptable and provides a better reflection of activities of daily living than other walk tests [17, 18, 20]. The American Thoracic Society has endorsed and published guidelines for performing the 6MWT in clinical settings [4].

The 6MWT can be repeated at low cost , unlike cardiopulmonary exercise testing with metabolic monitoring which requires expensive equipment, technical expertise and training of the subject [4, 21].

Previous studies have validated the 6MWT as predictive and it seems an appropriate method to evaluate exercise tolerance in heart failure (HF), as well as a better representation of actual exertion in daily living activities [22-24].

Various studies on walk tests used 10-m, [25] 15-m, [26] and 400-m tracks [27] whereas the 6MWT is most commonly used [28-30] Several studies have been conducted using this test in patients, [31] healthy adults [32] and children [33, 34].

Recently a review articles have been published on validity, reliability and responsiveness of 6MWT [35] and implication of 6MWT as a self-administered assessment tool [10].

Correlation study between a self-administered, adapted Six Minute Walk Test (the Home-Heart-Walk) and the standard Six Minute Walk Test has been reported [36]. R A Adedoyin, et al. assessed the functional capacity during a 6-minute corridor walk and a 6-minute bicycle ergometry exercise in patients with chronic heart failure (CHF) [37].

Kira P. Prahm, et al. concluded that a modified 6-minute walk test, by correcting walking distance with average heart rate during walking, decreases the variability among repeated 6-minute walk tests [38].

There is no clear relation between beat by beat heart rate and the measured distance has been reported during 6MWT. Furthermore, we did not find any evidence that support or denies the change in beat by beat heart rate slopes during 6MWT among different healthy adults. Thus, it was hypothesized that measuring the beat by beat heart rate slopes during 6MWT among different subjects would help to establish this connection. Thus, in the current study, we aimed to establish normal reference standards for beat by beat heart rate slope and recovery slope instead of depending on the covered distance to predicate and estimate the level of physical fitness during 6MWT of healthy adult students aged between 18–27 years in Saudi Arabia.

Materials and methods

Seventy (70) healthy male adult students were recruited randomly from the general Saudi population in Riyadh. Before recruitment, a health talk was given at each participating to explain the purpose of the study and informed consent obtained from the participant.

A questionnaire was completed prior to 6MWT that provided information about their medical history to help identify any medical condition that might be a contraindication to 6MWT [39].

Individuals with signs of cardio and pulmonary were excluded. Only normal healthy subjects between 18 to 27 years of age were included in this study. Subject's weight and standing height were measured with a calibrated weighing scale in kilograms and inch tape measurements in centimeters.

The body mass index of the sample is categorized into normal weight, overweight and obese. They were categorized as (62.3%, 14.5% and 23.1%) respectively. Sample was selected randomly to give every healthy adult Saudi male student a chance to be selected in our study. The study was carried out in four (04) months.

Various settings and materials were appropriately used during this study, which include: A 50m long, solid and flat field,[40, 41]. A heart rate monitor (GARMIN - HRM1B) which detects a beat by beat pattern of the heart rate, Sport monitoring watch (GARMIN - forerunner 50), USB ANT Stick to wirelessly send workout data to the computer.

Study measurements

Heart rate monitor was placed directly on the skin of the subject (directly on the apex beat), and the stopwatch was set to 6 minutes. Syncing between the watch with the heart rate monitor is made. Then, the subject wore the watch and gave him instructions on how to perform the 6MWT. The test consist of two main phases: 6MWT is performed at first and is followed by a resting period of 3 minutes as a recovery stage. The 6MWT conducted according to the standardized protocol [4]. Subjects were instructed to walk from one end to the other of a 50 meter hallway at their own place, while attempting to cover as much ground as possible in the allotted 6 minutes. Borg rating of perceived exertion (BRPE) scale is used to assess the participant exertion during the test.

Subjects were instructed to walk from one end to the other of 50 meter hallway at their own place, while attempting to cover as much ground as possible in the allotted 6 minutes. Afterwards, 6MWT and Initial beat by beat heart rate readings were recorded simultaneously for each participant, walked alone, not with other subjects. Using of standardized phrases while speaking to the subject [42] a close supervision over the subject was maintained throughout the test. As soon as the 6 minutes completed, the heart rate monitor reading and a second BRPE scale were taken. After that, the participant asked immediately to sit to start the recovery stage for 3 minutes. The heart rate was measured each minute in the recovery stage. Subsequently, Data was uploaded to the computer.

Statistical analysis

All statistical analyses were performed using both SPSS statistical software (SPSS version 22.0) and (Origin Lap-version 9.1) software package. The data were presented as the mean ± standard deviation (SD). For all tests, $p < 0.05$ was considered significant.

Measuring the descriptive statistics, heart rate slopes and correlative relations were done in both these phases to make a comparative study using two tailed t-test. To minimize the prediction error of any variables of the 6MWT a stepwise linear regression slopes were used. To validate the regression equation, about 20% of subjects which chosen randomly was used as control group, while the remaining included for predictive equation group. In order to establish the most accurate relation between actual distance, walked by the different subjects and the measured heart rate slopes were also compared. In addition, a comparative perspective with previous studies was done to establish the most dependent factor used during 6MWT.

Measuring the heart rate slopes for every individual achieved by using (Origin Lap). The heart rate values were put along the y axis (dependent axis) of the plot for each separate subject, while the x axis (independent axis) represented time and its values were constant and incremented by 5, starting from 0 to 540 seconds. The data were divided for each subject into two groups based on the independent axis (time). Hence, two slopes (6MWT and recovery slope) were calculated for each subject. Both 6MWT slopes and recovery slopes were calculated using a semi log plot (lin-log plot). A lin-log plot uses a logarithmic scale on the x-axis, and a linear scale on the y-axis.

Results

The general characteristics of the 70 healthy adult Saudi male students (Age18 to 27 years with mean 21.6±1.8 years) were as per **Table - 1**. Six (6) subjects were excluded due to failure to obtain a full beat by beat 6MWT.

The mean walked distance was 470.5±64.6 meter and range from 350m to 650m. During the 6MWT, the maximum predicted heart rate percentage of total subjects reached 55.7±8.9 % and ranged from 27.0% to 76.3%. The BRPE values at the start of the test is constant and equals to 7, while the BRPE values at the end of the test are range from 8 to 11 with a mean of 9±1. The body mass index of the sample is categorized into normal weight, overweight and obese. They were categorized as (62.3%, 14.5% and 23.1%) respectively.

Table - 2 shows that there was a significant positive correlation between the 6MWTS and the recovery slope ($r= -0.460$, $p <0.001$), 6MWTS and the covered distance walked by the subjects ($r= 0.264$, $p<0.05$) and the recovery slope and the distance is present, ($r= -0.249$, $p <0.05$).

Table - 3 summarizes the calculated stepwise regression model was used in the analysis to find an equation for each significant correlation. The outcome of the stepwise regression models was the walked distance, 6MWTS and the recovery slope can be predicted by different equations. The distance can be predicted by knowing the 6MWTS (r^2= 0. 069602), (**Figure - 1**). The 6MWTS can be predicted by acquiring the recovery slope (r^2= 0. 211622), (**Figure - 2**). The recovery slope is also predicted by obtaining the 6MWTS (r^2= 0. 211622), (**Figure - 3**).

Six minute walk test distances (6MWTD), recovery slope and six minute walk test slope (6MWTS) were also correlated with physical characteristics (age, height, weight, BMI and BSA and BPRE scale).

Discussion

Given the rising prevalence of chronic devastating diseases, the evaluation of physical abilities is an important issue in routine clinical practice. These diseases are generally accompanied by exercise intolerance, which contributes to a reduction in the patient’s physical activity. Exercise intolerance often occurs in a context of prior sedentary lifestyle and hypoactivity induced by co-morbidities. Furthermore, exercise intolerance may be related to several aetiological factors: heart failure, peripheral impairments of the muscles and/or the microcirculation, neuro-hormonal impairments, metabolic disorders affecting the skeletal muscles, ageing and common co-morbidities.

Table – 1: Study population characteristics

	Mean ± SD
Age (years)	**21.6 ± 1.8**
Weight (kg)	**75.97 ± 19.10**
Height(cm)	**173.20 ± 6.89**
Distance (m)	**470.52 ± 64.66**
Start HR*	**87.26 ± 16.03**
Final HR*	**111.32 ± 16.24**
6MWT* slope	**0.0002 ± 0.0003**
Recovery slope	**-0.0005± 0.0003**
BMI*	**25.34 ± 6.21**
BSA*	**1.89 ± 0.23**
BRPE*	**9.02 ± 0.95**
MPHRP*	**55.79 ± 8.96**

***HR= Heart rate, 6MWT= six minute walk test, BMI = Body mass index BSA= Body surface area (BSA=$\sqrt{(W \times Ht)/6}$), BRPE= Borg Rating of Perceived Exertion, MPHRP= Maximum predicted heart rate percentage, MPHRP = ([final HR / (220 – age) ×]100**

Table - 2: Correlations

		Age	**Weight**	**Height**	**Distance**	**6MWT slope**	**Recovery Slope**	**BSA**
Age	Pearson Correlation	1	.036	.015	.076	.169	-.243*	.035
Weight	Pearson Correlation	.036	1	.208	-.187	-.133	-.006	.986**
Hight	Pearson Correlation	.015	.208	1	-.035	-.106	.087	.359**
Distance	Pearson Correlation	.076	-.187	-.035	1	.264*	-.249*	-.191
6MWT Slope	Pearson Correlation	.169	-.133	-.106	.264*	1	-.460**	-.148
Recovery slope	Pearson Correlation	-.243*	-.006	.087	-.249*	-.460**	1	.019
BSA	Pearson Correlation	.035	.986**	.359**	-.191	-.148	.019	1

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

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

The resulting decrease in physical ability reduces the level of physical activity, reduces the subject's participation in social activities and, in some cases, work activities [43].

Most of the daily activities are performed at sub maximal levels of physical exertion, and it has been proposed that sub maximal functional tests are a better reflection of physical capability [44].

The ability to walk a set distance is a quick, easy and inexpensive way to assess physical function [16].

Principally the six-minute walk test (6MWT), constitute a safe, useful submaximal tool for exercise tolerance testing in cardiac rehabilitation (CR). The 6MWT result reflects functional status, walking autonomy and efficacy of CR on walking endurance, which is more pronounced in patients with low functional capacity (heart failure – cardiac surgery). The 6MWT result is a strong predictor of mortality. However, clinically significant changes and reliability are still subject to debate – probably because of the ambiguity in terms of the target speed (either comfortable or brisk walking) [43]. The present study was the first study to validate a protocol to evaluate the beat-by-beat heart rate slopes during 6MWT in healthy male adults. This may be used to obtain the predicted 6MWD for individual subjects aged between 18 and 27 years performing the test for the first time, when using the standardized protocol.

Table – 3: Regression analysis

Dependent variables	**Independents variables**					
	Constant	**6MWT slope**	**Distance**	**Recovery slope**	**SEE**	**R^2**
Distance	458.725165	65085.630050	__	__	29071.855218	0.069602
6MWT slope	0.000006	__	__	-0.355038	0.083719	0.211622
Recovery slope	-0.000385	-0.596055	__	__	0.140552	0.211622

***SEE=standard error of estimation**

Figure – 1: Predicted distance based on the recovery slope using the following equation:
Distance = 458.725+ (6MWTS x 65085.630050))

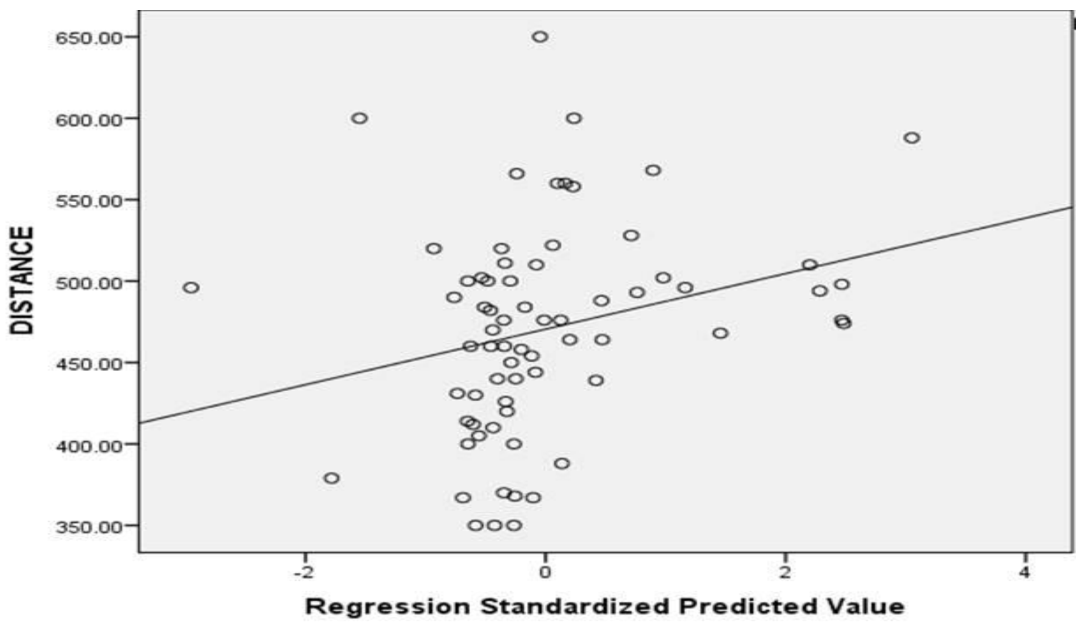


Figure – 2: Predicted 6MWT slope based on the recovery slope using the following equation:
6MWTS = 0.000006+ (recovery slope x -0.355038))

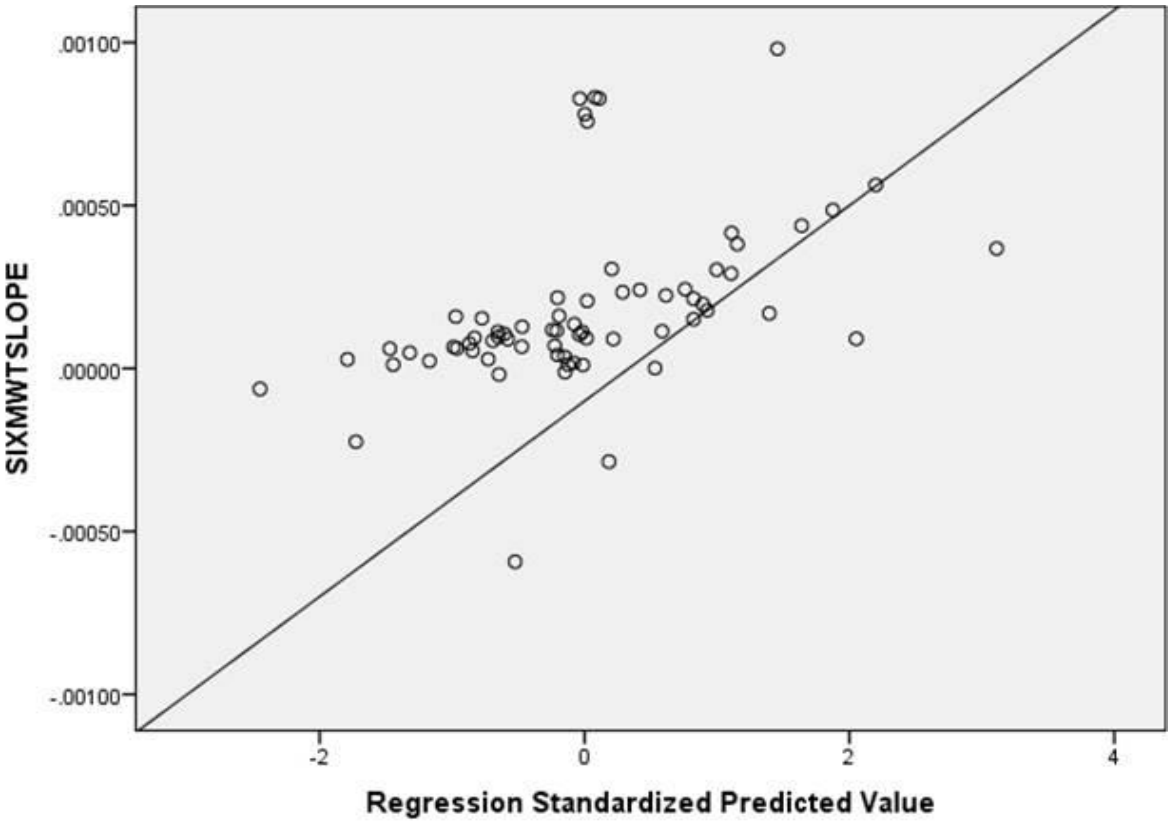
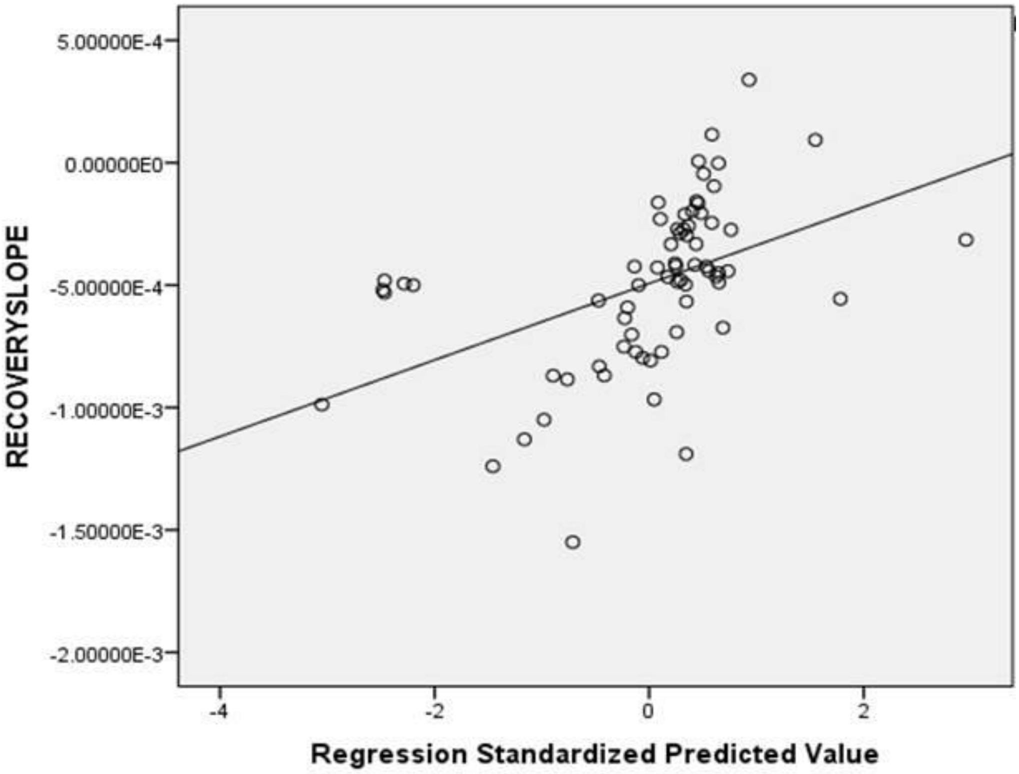


Figure – 3: Predicted recovery slope based on the 6MWT slope using the following equation:
Recovery slope = -0.000385 + (6MWTS x (-0.596055))



The 6MWT has become a standard in clinical practice and research as a simple tool to assess exercise performance, function and response to treatment in adults with cardiorespiratory disorders [4]. However, the measuring of 6MWTD has been controversial. The result of this test could be sometimes misleading and affects its reproducibility [4] due to different walk paces in different individuals, crowded corridor and the meander line the patients commonly walk in [42].

Both 6MWT slope and recovery slope were calculated using a semi-log plot. This kind of plot is useful when one of the variables being plotted covers a large range of values and the other has only a restricted range. The advantage being that it can bring out features in the data that would not easily be seen if both variables had been plotted linearly.

The mean 6MWTS of the sample size was 0.0002 ± 0.0003 and the recovery slope of the sample size was negative -0.0005± 0.0003 which represents a decline in beat by beat heart rate during recovery phase, the recovery slope shows a significant correlation with both distance and 6MWTS.

About seven significant correlations between important characteristics values and its significance were established (**Table - 2**) however, only three of them were in the scope of our study. Thus a significant correlation between 6MWTS and 6MWTD strongly indicating that 6MWTD can be replaced with 6MWTS as a measurement of physical fitness. Distance has a wide variability mainly due to alteration in subjects' height and other external factor like crowded corridor, so it is not entirely accurate measure of physical fitness [40-42]. On the regression analysis, stepwise model used to predict the equations for the distance, 6MWTS and recovery slope. Different prediction values and its equations were mentioned in the result section.

As several previous studies have shown a complete dependence on the 6MWD to measure the physical fitness, our study represents the first step toward establishing beat by beat heart rate recovery slop to predict the 6MWD based on the 6MWTS and recovery slope; thus, eliminating the need to measure the 6MWTD with obtaining the same level of result accuracy. We recommend adding of beat by beat recovery slop to 6MWT and using it as a clinical measurement of patient's fitness level.

Conclusion

The 6MWT is essential for the evaluation of exercise tolerance in several pathologies importance. It is safe, easy to administer, well tolerated, and reflects activities of daily living than other walking tests.

The present study was the first study to validate a protocol to evaluate the beat-by-beat heart rate slopes during 6MWT in healthy male adults. This may be used to obtain the predicted 6MWD for individual subjects aged between 18 and 27 years performing the test for the first time, when using the standardized protocol.

In our study, the 6MWD was measured only once in every adult. So we cannot provide information on the test – retest reliability. In spite of certain limitations, this study appears to confirm that the beat by beat heart rate recovery slop is a highly reliable and independent predictor of distance walked during the 6MWT.

In conclusion future investigations and studies are required to determine the reliability, validity and utility along with potential and clinical impact of this model.

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