Heart Rate Beat-to-Beat Slope Change during Six-Minute Walk Test: a Useful Clinical Tool for Estimating Fitness level

Fréquence Cardiaque Battement par Battement en Changeant la Pente pendant le Test de Marche de Six Minutes: un Outil Clinique Utile pour Estimer le niveau de Santé

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RÉSUMÉ

Introduction: Abstract: Le Test de Marche de Six Minutes (TM6M) est l'un des tests d'effort le plus courant et est utilise pour estimer le niveau de condition physique. Cette étude vise à évaluer la faisabilité de la fréquence cardiaque battement par battement TM6M en pente (TM6MP) et la pente de récupération pour la prévision et l'estimation du niveau de la condition physique pendant le test du TM6M, au lieu de dépendre de la distance parcourue pendant l'essai.

Méthodes: Soixante-dix sujets sains de sexe masculin adultes âgés de 18 à 27 ans ont été recrutés au hasard dans la population saoudienne générale à Riyad. En utilisation un couloir de 50 m, le TM6M a été effectué selon les directives normalisées de la Société Thoracique Américaine.

Résultats: La distance moyenne parcourue en 6 minutes (470,5 ± 64,6 m) et les fréquences cardiaques battement par battement (FCB) ont été calculées à l'aide d'un moniteur de FCB. En outre, l'indice de masse corporelle, la surface du corps, l'évaluation des efforts perçus le pourcentage maximal des FCB prédit ont également été calculés. Une équation de régression par étapes a été utilisée pour prédire la distance TM6M (TM6MD), TM6MP, et la pente de récupération. Il y a eu une corrélation significative entre TM6MP et la pente de recouvrement (r = -0,575, p <0,001); entre TM6MP et TM6MD (r = 0,414, p <0,001) et entre la pente de récupération et TM6MD (r = -0,454, p < 0,001).

Conclusion: Nos résultats suggèrent que les deux TM6MP et la pente de récupération peuvent prédire le TM6MD.

Mots-clés

SUMMARY

Introduction: The six-minute walk test (6MWT) is one of the most common exercise tests and is used to estimate the level of physical fitness. This study aimed to evaluate the feasibility of the beat-to-beat heart rate 6MWT slope (6MWTS) and recovery slope for predicting and estimating the level of physical fitness during 6MWT, instead of depending on the distance covered during the test.

Methods: Seventy healthy adult male subjects aged 18 to 27 years were recruited randomly from the general Saudi population in Riyadh. Using a 50-m corridor, 6MWT was performed according to standardised American Thoracic Society guidelines.

Results: The mean distance walked in 6 minutes (470.5±64.6 m) and beat-to-beat heart rate (HR) were calculated using a HR monitor. In addition, the body mass index, body surface area, Borg Rating of Perceived Exertion, and maximum predicted HR percentage were also calculated. A stepwise regression equation was used to predict the 6MWT distance (6MWTD), 6MWTS, and recovery slope. There was a significant correlation between 6MWTS and the recovery slope (r= -0.575, p<0.001), between 6MWTS and 6MWTD (r= 0.414, p<0.001), and between recovery slope and 6MWTD (r= -0.454, p<0.001).

Conclusion: Our findings suggest that both 6MWTS and recovery slope can predict 6MWTD.

Key-words

Heart rate, six-minute walk test, beat-to-beat heart rate slope, physical fitness, covered distance

In many chronic conditions, physical activity could improve physical fitness, reduce symptoms, and enhance quality of life (1,2). , several tests have been developed to evaluate the fitness of patients. One of these tests is the six-minute walking test (6MWT), which is a clinical sub-maximal exercise test for assessing functional capacity (3,4).

The six-minute walking test distance (6MWTD), measured during the 6MWT, is a good predictor of morbidity and mortality for various disease conditions in adults (5-7). The validity, reliability, and responsiveness of the 6MWT have been thoroughly investigated (8-10). A literature review of the 6MWT has revealed its potential as a self-administered, home-based monitoring tool (11). Traditionally, the 6MWT has been used to evaluate disease severity, progression, and response to treatment in patients with pulmonary arterial hypertension (12-16).

In recent years, investigators have focused on parameters other than 6MWTD to enhance the information obtained from the 6MWT. Tonelli et al (17) obtained real-time beat-to-beat heart rate (HR) acceleration and decay slopes during 6MWT in different patients with pulmonary arterial hypertension (PAH), other lung diseases, and healthy controls by using a portable impedance cardiograph. They hypothesised that the slopes of HR increase and decrease during the activity and recovery phase of the 6MWT. In addition they would differ 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 follow-up.

There is no clear relation between beat-to-beat HR slopes and 6MWTD reported during 6MWT. Furthermore, we did not find any evidence supporting or contradicting the presence of changes in beat-to-beat HR slopes during 6MWT among different healthy adults. Thus, we hypothesised that measuring the beat-to-beat HR slopes during 6MWT among different subjects would help to establish this connection. Thus, in the current study, we aimed to predict and estimate the level of physical fitness during 6MWT by calculating beat-to-beat HR slope in 6MWT and the recovery slope, instead of depending on 6MWTD.

METHODS

Seventy healthy male adults were randomly recruited from the general Saudi population in Riyadh. Data were collected from January 14, 2014, through May 15, 2015. The study was approved by the Ethics Committee of the Community Medicine Unit, King Khalid Hospital, King Saud University, Riyadh, Saudi Arabia. Before recruitment, the purpose of the study was adequately explained and informed consent obtained from participants.

A questionnaire was completed prior to the 6MWT to obtain information about patient medical history and to help identify any medical condition that might be a contraindication to 6MWT (18). Individuals with signs or symptoms of cardiac and pulmonary disease were excluded. Only normal healthy subjects between 18 and 27 years of age were included in this study. The weight and standing height of participants were measured with a calibrated weighing scale in kilograms and a tape measure in centimetres, respectively.

The body mass index of participants was categorised into normal weight, overweight, and obesity. The body surface area (BSA) was calculated using Mosteller’s formula (19). The study was conducted over a period of sixteen months.

Materials

Materials used during this study include the following: a 50-m long field (20,21), HR monitor (GARMIN - HRM1B) that detects a beat-to-beat pattern of the HR, sports monitoring watch (GARMIN - forerunner 50), and a USB ANT Stick to wirelessly send workout data to the computer.

Study measurements

The HR monitor was placed directly on the skin of the subject (directly on the apex beat), and the stopwatch was set to 6 minutes. The watch was synchronised with the HR monitor. After this, the subject wore the watch and was instructed on how to perform the 6MWT. The test consist of two main phases: the 6MWT is first performed followed by a resting period of 3 minutes. The 6MWT was conducted according to the standardised protocol (4). Subjects were instructed to walk from one end to the other of a 50-m field at their own pace while attempting to cover as much distance as possible in the allotted 6 minutes. The Borg Rating of Perceived Exertion (BRPE) scale, which is range between six and twenty rates was used to assess participant exertion during the test.

Subsequently, 6MWT and initial beat-to-beat HRs were recorded simultaneously for each participant, alone, and not with other subjects. Using standard phrases to communicate with the subject (22), the subject was closely monitored throughout the test. As soon as the 6 minutes were completed, the HR monitor reading and a second BRPE scale reading were taken. After this, the participant was immediately asked to sit and this recovery stage lasted for 3 min. The HR was measured at each minute in the recovery stage. Subsequently, the data were uploaded to the computer.

Statistical analysis

The noisy raw data of HR values were edited by applying a 95% confidence interval to a linear regression model and outlying data points were removed using a commercially available data analysis and graphics package (Origin Pro Version 8, OriginLab Corporation, Northampton, USA). The HR values were plotted 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 s, starting from 0 to 540 s (i.e. 360 s for 6MWT and 180 s for the recovery stage). The 6MWT slopes (6MWTS) and recovery slopes were calculated using linear fitting of beat-to- beat heart rate slopes. The data were divided for each subject into two groups based on the independent axis (time). Hence, two slopes (6MWTS and recovery slope) were calculated for each subject (Fig. 1).

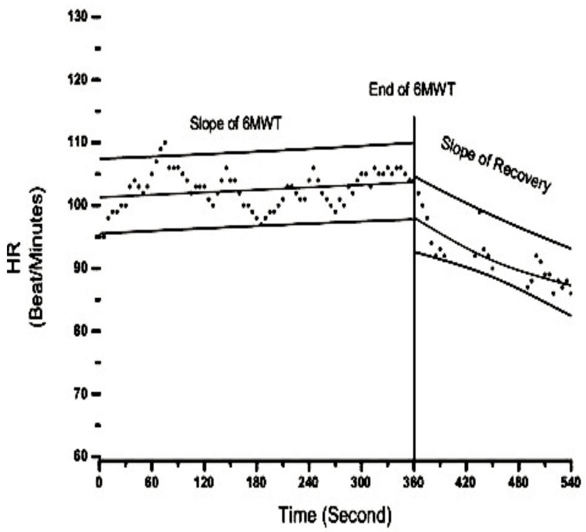

Figure 1 : . Heart rate slopes using OriginPro. Both the six-minute walk test (6MWTS) slopes and recovery slopes were calculated using linear fitting of beat-to-beat heart rate slopes. The slope was corrected to within the 95% confidence interval.

Descriptive statistics were used to summarise the demographic and clinical parameters in Table 1. All statistical analyses were performed using SPSS statistical software (SPSS version 22.0) and measurement of the HR slopes for each individual achieved using the Origin Pro version 8 software package and the slope corrected to 95% confidence interval. The data are presented as the mean ± standard deviation (SD). For all tests, $p < 0.05$ was considered significant.
Descriptive statistics, HR beat-to-beat slopes, and correlations were calculated for both phases (walk and recovery) to enable a comparison between them by using the two-tailed t-test. To minimise the prediction error of any 6MWT variable, stepwise linear regression slopes were used. To validate the regression equation, approximately 20% of the subjects chosen randomly were used as control group, while the remaining 80% were included in the predictive equation group. The actual distance walked by the different subjects and the measured HR slopes were also compared in order to elucidate any relationship between them. In addition, a comparison with previous studies was done to establish the most dependent factor during 6MWT.

RESULTS

The general characteristics of the 70 healthy adult Saudi male students (mean 21.6±1.8; range 18-27; years) are summarised in Table 1. Six subjects were excluded because of failure to obtain a full beat-to-beat 6MWT.

Table 1 : Characteristics of the Study population

Variables	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 (beats/min)	87.26 ± 16.03
Final HR (beats/min)	111.32 ± 16.24
6MWT slope	0.05 ± 0.05
Recovery slope	-0.11 ± 0.073
BMI (kg/m2)	25.34 ± 6.21
BSA (m2)	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= √[(W×Ht))/6], BRPE = Borg Rating of Perceived Exertion, MPHRP = Maximum predicted heart rate percentage, MPHRP = [final HR / (220 – age)] × 100

The mean 6MWTD was 470.5±64.6 m (range 350–650 m). During the 6MWT, the maximum predicted HR percentage of total subjects was 55.7±8.9% (range 27.0–76.3%). The BRPE values at the start of the test were constant (a value of 7), while the BRPE values at the end of the test ranged from 8–11 (mean 9±1). The proportion of patients who were of normal weight, overweight, and obese were 62.3%, 14.5%, and 23.1%, respectively.
Table 2 shows that there was a significant negative correlation between the 6MWTS and recovery slope (r= -0.575, p <0.001), 6MWTS and 6MWTD (r= 0.414, p>0.001), and the recovery slope and 6MWTD (r= -0.454, p >0.001).
Table 3 summarises the calculated stepwise regression model used in the analysis to find an equation for each significant correlation. The outcome of the stepwise regression models was the 6MWTD, 6MWTS, and recovery slope, which could be predicted by different equations.
The 6MWTD can be predicted using the recovery slope (r2= 0.212). The 6MWTS can be predicted by obtaining the recovery slope (r2= 0.331). However, when BSA was added as a correlating factor, there was a significant increase in the r-value (r2= 0.392). The recovery slope can also be predicted by obtaining the 6MWTS (r2=

Table 2. Correlation of six-minute walk test distance (6MWTD), recovery slope, and six-minute walk test slope (6MWTS) with physical characteristics.

	Age	Weight	Height	6MWTD	6MWT Slope	Recovery Slope	BSA
Age	1	0.036	0.015	0.076	0.144	-0.178	0.035
Weight	0.036	1	0.208	-0.187	-0.229	0.033	0.986**
Height	0.015	0.208	1	-0.035	-0.177	0.016	0.359**
6MWTD	0.076	-0.187	-0.035	1	0.414**	-0.454**	-0.191
6MWTSlope	0.144	-0.229	-0.177	0.414**	1	-0.575**	-0.253*
Recovery slope	-0.178	0.033	0.016	-0.454**	-0.575**	1	0.046
BSA	0.35	0.986**	0.359**	-0.191	-0.253*	0.046	1

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

Table 3. A stepwise regression equation to predict six-minute walk test distance (6MWTD), six-minute walk test slope (6MWTS), and recovery slope

Dependent variables	Independents variables						
	Constant	6MWTS	6MWTD	Recovery slope	BSA	SEE	R^2
6MWTD	422.3	-	-	-400.8	-	13.9	0.212
6MWTS Modal 1	0.005	-	-	-0.393	-	0.010	0.331
6MWTS Modal 2	0.104	-	-	-0.382	0.051	0.042	0.392
Recovery slope Modal 1	-0.075	-0.842	-	-	-	0.011	0.331
Recovery slope Modal 2	0.062	-0.680	0.001	-	-	0.058	0.391

0.331). Furthermore, by adding the 6MWTD as a correlating factor, there was an increase in the r-value (r2= 0.391). Table 3 summarises the calculated stepwise regression models mentioned above.

DISCUSSION

Given the increasing prevalence of severe chronic diseases, the evaluation of physical fitness is important in routine clinical practice, because these diseases are generally accompanied by exercise intolerance, leading to a reduction in the patient's physical activity. Exercise intolerance often occurs in the context of a previously 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, neurohormonal impairments, metabolic disorders affecting the skeletal muscles, ageing, and common co-morbidities.

The resulting decrease in physical ability reduces the level of physical activity, the subject's participation in social activities and, in some cases, work activities (23). For these set of persons, most daily activities are performed at submaximal levels of physical exertion, and it has been proposed that submaximal functional tests are a better reflection of physical capability (24).

Principally, the 6MWT is a safe, useful submaximal tool for exercise tolerance testing in cardiac rehabilitation (CR). The 6MWT results are representative of functional status, walking autonomy, and CR efficacy on walking endurance, which is more pronounced in patients with low functional capacity (heart failure, cardiac surgery, etc.). 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) (23).

The present study was the first study to vali¬date a protocol to evaluate beat-to-beat HR slopes during 6MWT in healthy male adults. This may be used to obtain the predicted 6MWTD for individual subjects aged between 18 and 27 years who were performing the test for the first time, when using the standardised protocol.

The 6MWT has become standard in clinical practice and research for assessing exercise performance, function, and response to treatment in adults with cardiorespiratory disorders (4). However, defining the standard protocol for measuring 6MWTD has been a source of disputation (21,25). The result of this test could be occasionally misleading which affects its reproducibility (4), due to different paces in different individuals, crowded corridors, and the meandering walk pattern of patients (22).

In previous studies (4,26), the 6MWTD was the dependent variable for determining the level of fitness. In this study, we used the beat-to-beat HR and calculated the slope of the sample during 6MWT in healthy male adults.

The mean 6MWTS of the sample size was 0.05 ± 0.05 and the recovery slope of the sample size was negative -0.11 ± 0.073, which represents a decline in beat-to-beat HR during the recovery phase. Interestingly, the recovery slope showed a significant negative correlation with both 6MWTD and 6MWTS ($p<0.001$).

About six significant correlations between important characteristics values were observed (Table 2); however, only three of them were investigated in our study. A significant correlation between 6MWTS and 6MWTD strongly indicated that 6MWTD can be replaced with 6MWTS and recovery slope as a measurement of physical fitness. 6MWTD has a wide variability mainly due to differences in subject height and other external factors like a crowded corridor, so it is not an entirely accurate measure of physical fitness (20-22). On the regression analysis, a stepwise model was used to predict the equations for 6MWTD, 6MWTS, and recovery slope. Different prediction values and their corresponding equations are shown in Table 3.

As several previous studies completely depended on the 6MWTD to measure physical fitness, our study represents the first step toward establishing the use of the beat-to-beat HR slope to predict 6MWTD based on the 6MWTS and recovery slope; thus, eliminating the need to measure 6MWTD, but with the same level of accuracy. We recommend the use of beat-to-beat recovery slope in 6MWT as a clinical measure of patient fitness level.

In our study, 6MWTD was measured only once in every adult; consequently, we could not provide information on the test-retest reliability. In spite of certain limitations, this study appears to confirm that the beat-to-beat HR 6MWTS and recovery slope are highly reliable and independent predictors of the distance walked during the 6MWT. However, future investigations and studies are required to determine its reliability, validity, and utility in different age categories.

CONCLUSION

The present study is the first study to validate a protocol to evaluate beat-to-beat HR slopes during 6MWT in healthy male adults. This may be used to obtain the predicted 6MWTD for individual subjects aged between 18 and 27 years performing the test for the first time when using the standardised protocol.

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