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Research Article

Physiology

Assessment of VO_2 Max Reliability with Garmin Smart Watch among Swimmers

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Abstract: Maximal aerobic capacity (VO_2 max) is one of the important factors that influence swimming performance. Currently, the Garmin Forerunner Fitness Watch 935 used to measure VO_2 max are expensive, require skilled-trained personnel, not feasible for large-scale use, and land-based, which will not be accurate in measuring water-based activity. In order to measure the swimming performance, there is a need for an affordable, feasible, and reliable device. Therefore, the current study aimed to examine the intra-rater reliability of Garmin Forerunner Fitness Watch 935 accuracy in measuring the VO_2 max among collegiate swimmers during the 200m swimming task. The VO_2 max measurement of 10 collegiate swimmers was taken with Garmin Forerunner for two trials. The intra-class correlation coefficient (ICC), standard error of measurements (SEMs), and Bland-Altman plot was used in the current study to establish the inter-rater reliability measurement. The intra-rater reliability of Garmin Forerunner showed high reliability and accuracy with an intra-class correlation coefficient (2,1) of 0.869 and standard error of measurements of 0.231 ml/kg/min. Further, the results were strengthened with Bland-Altman plot showed an acceptable agreement between the two trials. The Garmin Forerunner would be a simple, objective and useful device to be used by physiotherapists, trainers and other sports-related disciplines to assess and improve the swimming performance by targeting the heart rate and VO_2 max.

Keywords: Oxygen Consumption, Swimming, Reliability, Fitness tracker, VO_2 max, Garmin Forerunner Fitness Watch 935.

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1. INTRODUCTION

In the modern era, swimming has been popularized and has been a regular part of exercise and sport activity. For the improvement of swimming performance, maximal aerobic capacity is a vital component that needs to be assessed and monitored as many previous studies have shown a significant relationship between these variables.[1–5] Maximum oxygen consumption has been denoted as one of the best objective measures that can be used to examine the aerobic endurance capacity.[2,6] Maximum oxygen consumption is usually represented as VO_2 max and is defined as the highest capacity of oxygen that a person can consume and spend during one minute of exercise.[7] One of the reliable methods in the measurement of VO_2 max is to examine the relationship between heart rate and oxygen uptake during the exercise procedure.[2] The VO_2 max among the swimmers can be measured based on the exercise–based tests or non-exercise tests such as the direct VO_2 max laboratory test, indirect submaximal (treadmill, ergometer, step test), Cooper's 12-minute test, and other tests.[4,5,8] Nevertheless, the currently used method often requires expensive equipment, skilled-trained personnel, not feasible for large-scale use and interruption of scheduled follow-up session. Moreover, most of the equipment would not be accurate for actual physical performance measurement as the devices need laboratory settings, oriented to be used either in the diseased population such as cardio-respiratory disorders or in high level trained athletes.[8] Hence, a more affordable, convenient to be used in water activities, applicable in real life and validated device, Garmin Fitness Forerunner 935 was selected to evaluate the VO_2 max among the swimmer. [9] Recently, many wearable watches have emerged in monitoring physical activity functions as well as in clinical and research settings.[10] Previous studies on wearable watches were limited to the validity of energy expenditure, stroke counts, swimming speed, swimming style recognition, lap counting [10,11] as well as the measurement of VO_2 max on the land-based settings.[12] To monitor the VO_2 max during swimming performance, land-based measurement will not be accurate as studies have reported the differences in peak heart rate (HR max) during swimming to be lower compared to running as the different body position plane, reduced gravity effects, minimum need of muscle mass as well as hemodynamics changes.[13–15] Few studies have been reported about the reliability of Garmin Fitness Forerunner in measuring aerobic capacity.[16,17] Nevertheless, the reliability of Garmin Fitness Forerunner in measuring VO_2 max among the swimmers is not established so far. Thus, the objective of this research is to examine the intra-rater reliability of the Garmin Forerunner Fitness smartwatch to measure the Vo_2 max during the 200m swimming task among collegiate swimmers.

2. MATERIALS AND METHODS

2.1 *Participants*

Ten healthy (5 male, 5 female) participants (mean ± SD: age 22 ± 1.83years) were recruited in the current study Participants should be freestyle swimmers and expected to swim a minimum of 1 hour per week. Participants with central nervous system disorders (seizure, epilepsy), respiratory disorders, previous injuries of the upper limb or lower limb, BMI greater than 24 kg/m2 and undergoing other training regimens aside from swimming were excluded from the current study.[11,12] The first author explained the study methodology and written informed consent obtained. The Faculty Research and ethical committee approved the research project, which was under the university seeding grant (IU Research Seed Grant 2018: INTI-FHLS-01-05-2018). Experiments were done in accordance with revised Helsinki Declaration of 2000.

2.2 *Procedure*

Garmin Forerunner 935 Fitness Watch (Garmin International, Inc., Kansas, United States) used to assess the swimmers' VO_2 max. The participants' weight and height were recorded in the Garmin watch interface. A heart rate strap was secured on the participant's chest and synchronized to the Garmin watch to monitor the procedure's maximum heart rate. The smart watch were set in pool-swim mode, and participants were instructed to press 'Enter' to capture data. Participants swam about 200m in the Olympic sized pool according to their own average pace. Upon completion, the participants were asked to press 'Enter' again to save the Garmin Connect App data. A single researcher throughout the study examined the participants on the time taken for completion, max HR, and VO_2 max. Two trials were conducted for each participant with a period of one-hour rest interval. The procedure for the current study were established following the guidelines for reporting reliability and agreement studies (GRRAS).[31]

3. STATISTICAL ANALYSIS

The data from the Garmin Connect App transferred and analyzed using the Microsoft Office Excel 2016 (Microsoft Corporation, USA)and Statistical Software PackageSPSS(Version26.0).Garmin Watch's reliability was analyzed using the intra-class correlation coefficient (ICC) and the standard error measurement (SEMs). The ICC indicates the correlation between the trials whereby a correlation of 0.75 to 1.00 dictates an excellent correlation.[20,21] Whereas SEMs denotes the reliability of the measurements if less than 5%.[20,21] To further strengthen the study result, the Bland-Altman plot was employed to examine the two trials' agreement.[22]

4. RESULTS

The participants finished the trials and data were distributed normally. Table 1 shows the mean and standard deviation of Trial 1 and 2 for VO_2 max during the 200m swimming. Table 2 represents the ICC and SEMs values of the swimming trials using the Garmin Fitness Watch. The watch showed an excellent reliability as the ICC (2,1) shows a value of 0.869. The SEMs also indicate a high reliability with a value of 0.231 ml/kg/min. In the Bland-Altman plot, the measurement of Trial 1 and Trial 2 falls in between ± 2SD which specifies a good agreement [Fig 1] as all the trials falls within the agreement range of ±1.96 SD.

Table 1: The descriptive analysis of the participant's demographics characteristics [Mean ± SD]		
Mean (SD)	**Trial 1**	**Trial 2**
Time taken to complete 200m	3.340 ± 0.47	3.271 ± 0.41
Max heart rate (bpm)	169.8 ± 9.55	161.8 ± 8.89
VO^2 max (ml/kg/min)	42.10 ± 1.45	42.00 ±1.61

Values are mean ± SD; (n=10)SD – Standard deviation

Table 2: Interrater reliability analysis of Trial 1 and Trial 2 of VO_2 max among the collegiate swimmers		
	ICC	**SEMs**
VO^2 max (ml/kg/min)	0.869	0.231

ICC – Intraclass Coefficient, SEMs – Standard Error of Measurement

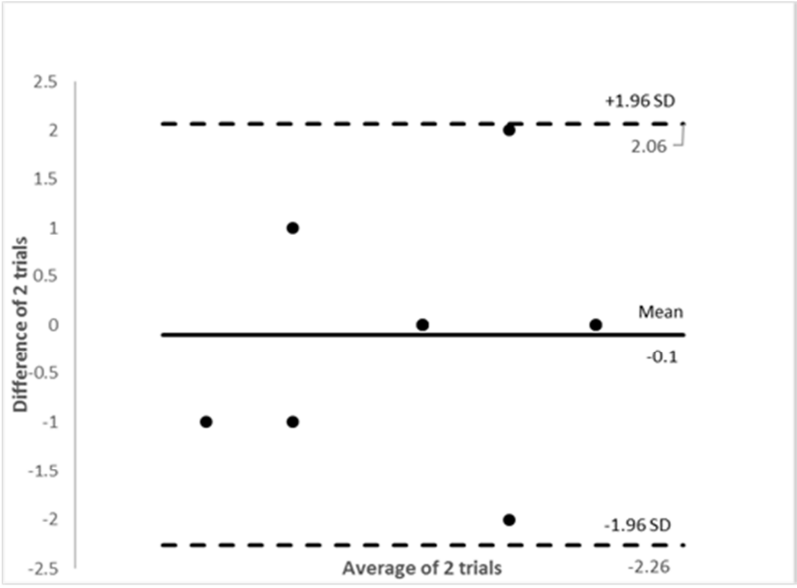

Fig 1: The measurement agreement of trial 1 and 2 of VO_2 max between the Collegiate swimmers using the Bland-Altman plot

5. DISCUSSION

The study examined the reliability of Garmin Fitness Forerunner 935 in measuring the maximum aerobic capacity (VO_2) during 200m swimming among collegiate swimmers. In the present study, the ICC values of 0.869 showed high reliability with a good range of SEMs (0.231 ml/kg/min). The plotting of Bland Altman showed a good agreement between two measurements of VO_2 max. Hence, the present study results established good reliability for Garmin Fitness Forerunner 935 to examine the swimmers VO_2 max. The current study results also supported by previous study as the researcher has examined the reliability of the Garmin Forerunner 920XT Fitness Watch in measuring the VO_2 max during maximal aerobic capacity test and a field-endurance-run.[30,] Although there are many devices to measure the VO_2 max[9,12,16,30], most often it can be used only on land measurement and not suitable for underwater activities. Consequently, the swimmer's VO_2 maximum on land-based test is not appropriate as the peak heart rate (HR max) has been reported lower during swimming than running due to the horizontal body position, reduced gravity effects, reflex bradycardia, lesser amounts of required muscle mass, and hemodynamics changes,[13–15] and this was justified as swimming needs less muscle mass and different body position, which generate higher hydrostatic pressure and reduced perfusion in the working muscle's capillary bed.[23] These changes cause a reduction in both blood flow and oxygen transport and indirectly affect the different VO_2 max value outcomes in both cycle ergometer and swimming.[23] Thus, there is a need for a more reliable and accurate water-based device to measure the VO_2 max among swimmers. The current study recognizes the limitation of Garmin Forerunner 935's such as the wristwatch's sensitivity, consistent, coordinated movement, and fatigue. The sensitivity of wrist-mounted devices is often unpredictable.[24] Nevertheless, in the current study, a heart rate strap was also secured on the participant to yield an accurate and reliable measurement. Several studies have reported that swimming speed consistency depends on swimming speed, [25,26] the dominance of the arm,[27] energy consumption,[28] the intensity of exercises,[29] and the level of expertise.[25] Thus, the current study predicts that swimming coordination would be affected during the two trials of 200mTherefore, to minimize the inaccuracy of heart rate and VO_2 max monitoring, the participants were instructed to swim at their own regular pace. Likewise, continuous swimming for two trials may exhibit discomfort and fatigue among the collegiate swimmers. Therefore, participants were asked to swim only 200m with a one-hour interval between the attempts to prevent fatigue, swimming speed, and stroke changes. Future study is recommended to be investigated among elite professional swimmers to acquire better findings.

6. CONCLUSION

The Garmin Forerunner Fitness Watch 935 can measure the

VO_2 max with high reliability among the swimmers. The Garmin would be an easy and objective device that can monitor, assess, and improve swimmers' performance by targeting the heart rate and VO_2 max.

7. FUNDING ACKNOWLEDGEMENTS

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8. AUTHORS CONTRIBUTION STATEMENT

Mr. Sivaguru, Dr. Balasubramanian and Ms. Ambusam conceptualized the current study. Data was gathered by Mr. Sivaguru and Mr. Vinosh. Ms Ambusam and Mr. Rajkumar Krishnan Vasanthi analyzed these data and necessary inputs were given towards the designing of the manuscript. All authors discussed the methodology and results and contributed to the final manuscript.

9. CONFLICT OF INTEREST

Conflict of interest declared none.

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