The validity of fitness watches synced with an accelerometer for measuring spatiotemporal parameters during running

ความเที่ยงตรงของนาฬิกาออกกำลังกายที่เชื่อมต่อกับอุปกรณ์วัดความเร่งสำหรับการประเมินพารามิเตอร์ด้านเวลาและระยะทางขณะวิ่ง

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ABSTRACT

Background: Fitness watches can track many metrics such as daily step counts, heart rate, and sleep quality, etc. When they synced with accelerometers can also provide valuable information about spatiotemporal parameters during running such as cadence, ground contact time, stride length, and vertical oscillation. To use these devices as research tools, an investigation is needed to determine their validity.

Objective: To validate spatiotemporal parameters derived from fitness watches and accelerometers compared to those same parameters obtained from a video gait analysis system such as walker view treadmill.

Methods: Thirty-four active runners who have had no leg injuries for the past 6 months were recruited (age 38.89±6.79 years, weight 64.17±10.62 kg, height 168.57±8.53 cm, and BMI 22.41±1.84 kg/m^2). They wore fitness watches synced with an accelerometer and ran for 2 minutes on a walker view treadmill. This treadmill was used as a gold standard since it was equipped with a 3D camera, foot sensors, and a force platform. Spatiotemporal parameters from fitness watches synced with accelerometers were then compared to these same parameters that were obtained from a walker view treadmill.

Results: The validity of cadence, ground contact time, stride length, and vertical oscillation, indicated by the intraclass correlation (ICC 3,1) was 0.99, 0.94, 0.86, and 0.80, respectively. Cadence and ground contact time showed excellent validity while stride length and vertical oscillation demonstrated good validity.

Conclusion: Fitness watches synced with an accelerometer can provide good to excellent validity compared to a walker view treadmill when measuring spatiotemporal running parameters.

Keywords: fitness watches, cadence, ground contact time, stride length, vertical oscillation

บทคัดย่อ

ที่มาและความสำคัญ: นาฬิกาออกกำลังกายสามารถติดตามตัวชี้วัดต่าง ๆ เช่น การนับก้าวในแต่ละวัน อัตราการเต้นของหัวใจ และคุณภาพการนอนหลับ เป็นต้น เมื่อนาฬิกาออกกำลังกายเชื่อมต่อกับอุปกรณ์วัดความเร่ง ให้ข้อมูลที่มีประโยชน์เกี่ยวกับพารามิเตอร์ด้านเวลาและระยะทางในขณะวิ่ง เช่น รอบขา ระยะเวลาที่เท้าสัมผัสพื้น ระยะก้าว และการกระเด้งตัวในแนวดิ่ง เพื่อที่จะสามารถใช้อุปกรณ์ดังกล่าวในงานวิจัย การทดสอบความเที่ยงตรงเป็นเรื่องจำเป็นที่ต้องพิสูจน์

วัตถุประสงค์: เพื่อตรวจสอบความเที่ยงตรงของพารามิเตอร์ด้านเวลาและระยะทางขณะวิ่ง ที่วัดได้จากนาฬิกาออกกำลังกายที่เชื่อมต่อกับอุปกรณ์วัดความเร่ง

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Received: 15 Feb 2024; Revised: 01 Apr 2024; Accepted: 15 May 2024

เปรียบเทียบกับตัวแปรที่วัดได้จาก ระบบวิเคราะห์วิดีโอการเดิน เช่น ลู่วิ่งไฟฟ้าที่มีเซ็นเซอร์และกล้องวีดิโอบันทึก

วิธีการวิจัย: นักวิ่งที่ซ้อมวิ่งอย่างสม่ำเสมอ จำนวน 34 คน ที่ไม่มีอาการบาดเจ็บของรยางค์ขาส่วนล่างในช่วง 6 เดือนที่ผ่านมา (อายุ 38.89±6.79 ปี น้ำหนัก 64.17±10.62 กิโลกรัม ส่วนสูง 168.57±8.53 เซนติเมตร และดัชนีมวลกาย 22.41±1.84 กิโลกรัม/ตารางเมตร) นักวิ่งสวมนาฬิกาออกกำลังกายที่เชื่อมต่อกับอุปกรณ์วัดความเร่งและวิ่งเป็นเวลา 2 นาทีบนลู่วิ่งไฟฟ้าที่มีเซ็นเซอร์และกล้องวีดิโอบันทึก ลู่วิ่งไฟฟ้านี้จัดเป็นเครื่องมือมาตรฐานระดับสูง ซึ่งประกอบด้วยกล้อง 3 มิติ เซ็นเซอร์เท้า และแผ่นวัดแรง ดังนั้น ค่ารอบขา ระยะเวลาที่เท้าสัมผัสพื้น ระยะก้าว และการกระเด้งตัวในแนวดิ่ง ที่วัดจากนาฬิกาออกกำลังกายกับอุปกรณ์วัดความเร่งเปรียบเทียบกับตัวแปรที่วัดได้จากลู่วิ่งไฟฟ้าที่มีเซ็นเซอร์และกล้องวีดิโอบันทึก

ผลการวิจัย: ความเที่ยงตรงของรอบขา ระยะเวลาที่เท้าสัมผัสพื้น ระยะก้าว และการกระเด้งตัวในแนวดิ่ง ที่ระบุโดยค่าสัมประสิทธิ์สหสัมพันธ์ภายในชั้น (ICC 3,1) เท่ากับ 0.99, 0.94, 0.86 และ 0.80 ตามลำดับ ความเที่ยงตรงที่สูงมากได้รับการยืนยันในการวัดค่ารอบขา ระยะเวลาที่เท้าสัมผัสพื้น และความเที่ยงตรงที่สูง ได้รับการยืนยันในการวัดระยะก้าว และการกระเด้งตัวในแนวดิ่ง

สรุปผล: ในการวัดพารามิเตอร์ด้านเวลาและระยะทางขณะวิ่ง นาฬิกาออกกำลังกายที่เชื่อมต่อกับอุปกรณ์วัดความเร่ง ให้ความเที่ยงตรงในระดับสูงมาก และสูงเปรียบเทียบกับตัวแปรที่วัดได้จากลู่วิ่งไฟฟ้าที่มีเซ็นเซอร์และกล้องวีดิโอบันทึก

คำสำคัญ: นาฬิกาออกกำลังกาย รอบขา ระยะเวลาที่เท้าสัมผัสพื้น ระยะก้าว การกระเด้งตัวในแนวดิ่ง

Introduction

Recently, the health and wellness sector has experienced significant growth.[1] When discussing health tools, it's impossible not to mention fitness watches. Fitness watches have consistently been one of the top three most widely sold health and wellness devices since 2016.[2] They can track various metrics, including the number of steps taken, heart rate, sleep quality, fitness performance, and running biomechanics.[3-9] Tracking steps is a commonly utilized method for estimating daily physical activity levels. Recently, research has shown that tracking steps in daily life is an accurate and practical method based on lab results. High validity (Intraclass correlation coefficient; ICC = 0.85-0.92) for three fitness watches (Yamax 3D Power-Walker, Garmin Vivofit 3, and Medisana Vifit) has been reported in tracking step data.[7] Fitness watches are increasingly popular, and users can improve their adherence to physical activity and sedentary behavior thresholds outlines based on daily step counts.[10,11] They are also equipped with optic sensors to measure heart rate, and previous studies have reported high accuracy in this regard, as well. This highlights the potential of fitness watches as valuable instruments for monitoring cardiovascular health. However, it is essential to note that the precision of heart rate measurements may vary depending on the model or brand.[3, 5, 6, 8, 12]

Sleep patterns can be determined by using gyroscopes or accelerometers to monitor movement and optic sensors to monitor heart rate variability, in conjunction with an algorithm. They can measure sleep quality and duration and specify sleep phases such as light, deep, and rapid eye movement (REM) sleep. However, questions have been raised about the validity of the data. A comparison of fitness watches (Fitbit) and electroencephalography (EEG) has been investigated. Fitbit devices underestimated sleep onset latency by ~11 minutes and overestimated sleep efficiency by ~4%. There was no statistically significant difference between Fitbit and EEG methods in measuring wake after sleep onset and total sleep time. Fitbit showed substantial agreement with EEG in detecting REM and deep sleep, but only moderate agreement in detecting light sleep.[4] In contrast, previous research showed low to moderate levels of validity (ICC = 0.15-0.64) of Samsung Galaxy watches compared with polysomnography.[12] These different findings imply that variability of validity is evident in fitness watches.[8,12] Even though fitness watches have some inaccuracies as mentioned above, the limitations of EEG devices become apparent because they are usually used in sleep labs during the night, and the electrodes attached to the scalp can be uncomfortable and may interfere with natural sleep. Therefore, fitness watches are more convenient and affordable and can help track sleep better throughout the night.

In addition, fitness watches are beneficial in enhancing fitness performance based on heart rate zone training such as easy, aerobic, submaximal, and maximal. They also can estimate energy expenditure (EE) and maximal oxygen uptake (VO_{2max}).[6] Parak et al reported that fitness watch estimated EE was quite accurate during higher intensity activities.[13] However, a recent systematic review and meta-analysis study showed inaccuracy in estimating EE of nine different fitness watches.[6] For VO_{2max} detection, fitness watches showed accuracy during submaximal intensity in healthy subjects[13] and during maximal intensity in a population of athletes.[14] These indirect measures still vary depending on the manufacturer and type or model of device.

Fitness watches synced with accelerometers could have the potential to monitor running parameters such as cadence, ground contact time, stride length, and vertical oscillation. To test validity, these parameters derived from watches have been compared with the 3D motion as a gold standard measurement. However, 3D motion comes with high costs and technical demands, need time to attached electrodes and camera setting as well as require professional assistance to use.[15,16] Then, video gait analysis system such as walker view treadmill has been used instead of 3D motion due to it is economical, less technical demands and friendly to use. In addition, good to excellent validity of stride length and cadence (ICC = 0.7-0.99) measured by walker view treadmill found compared with 3D motion.[17] Poor validity of ground contact time (ICC = 0.03-0.14) illustrated, we considered this point, however, we believed that 8 load cells in walker view treadmill could overcome this limitation.

It is widely recognized that dynamic running parameters such as cadence, stride length, ground contact time and vertical oscillation, often referred to as spatiotemporal parameters, play a crucial role in both running performance (VO_{2max} and EE) and the risk of injuries. Several studies have investigated the effects of manipulating these spatiotemporal parameters on running performance and injury risk.[18-23] Specifically, altering these parameters can impact running performance and the risks of injuries. Reducing ground contact time or increasing stride length has been associated with faster running speeds.[18, 19] A shorter ground contact time can also contribute to reducing the vertical force exerted on the ground during running.[20,21] Additionally, modifying stride length is linked to changes in running performance and injury risk. Decreasing vertical oscillation (the upward and downward movement of the body during each stride) has been identified as a potential strategy to mitigate injury risk. Increasing cadence (the number of steps taken per minute) is another avenue for influencing these factors.[20-23]

Recently, previous studies reported high levels of reliability (ICC > 0.94) of four running parameters (cadence, ground contact time, stride length and vertical oscillation) either in laboratory settings.[24, 25] or in the outdoors.[26] For validity, good to excellent validity (ICC = 0.75-0.96) of cadence, vertical oscillation, and ground contact time measured by fitness watches (Garmin Fenix 2) synced with accelerometer (Garmin HRM) were confirmed compared with 3D motion.[25] These results show the same trends as the study of Smith et al that focused only on the vertical oscillation in fitness watches synced with four accelerometers (Incus Nova, Garmin HRM-Pro, Garmin Running Dynamic Pod, and Stryd Foot Pod) compared to video analysis. The results revealed that vertical oscillation measured by fitness watches synced with four accelerometers have moderate to excellent validity (ICC = 0.96, 0.75, 0.86, and 0.73, respectively). Therefore, these findings imply that the validity depends on brand of device or those having different specifications.[27] Moreover, the validity of stride length during running has not been investigated. However, there was a systematic review and meta-analysis that investigated stride length only during walking by using inertia measurement units. The results showed excellent validity.[28]

These four parameters are well-known contributors to both running performance and the risk of running injuries.[18-23] Several beneficial aspects of the fitness watches and accelerometers include convenience, comfort, and they are easy to sync with accelerometers and smartphones or computers to view the data on apps and websites and have alerts and alarms to provide feedback, guidance, and motivation for exercise goals. Given the controversial findings related to running parameters and the favorable attributes of fitness watches and accelerometers, this study, therefore, was specifically designed to assess the validity of cadence, ground contact time, stride length and vertical oscillation measured obtain from fitness watches synced with an accelerometer, as compared to those obtained from a walker view treadmill. We hypothesized that these four parameters could demonstrate good to excellent validity.

Methods

<u>Participants</u>

The sample size for this study was determined using G*Power software version

3.1.9.7, with an effect size set at 0.5, a power of 0.8, and a significance level of 0.05.[29] The minimum number of participants is thirty-four. Thirty-four physically active runners, who consistently engaged in running for a minimum of 150 minutes per week, participated in the study. Exclusion criteria were applied to individuals with a history of leg injuries or evidence of neurological symptoms.[26] During the experiment, they dressed in comfortable attire and wore their choice of running shoes. They refrained from intense physical activity for at least 24 hours before the test. Prior to the running test, participants were engaged in a general stretching routine that focuses on the lower limb area, including the thighs and calf muscles, etc. All participants provided their informed consent by signing forms before taking part in the research. The institution's ethical review committee for research in humans approved this consent procedure (approval number: AMSEC-64EX-110)

Fitness watch and accelerometer

A fitness watch (Garmin Forerunner 935, Switzerland) synced with accelerometer (Garmin Running Dynamic Pod, United states) was used in this study. Fitness watches provide measurements for cadence and stride length. When synchronized with an accelerometer, they offer all four essential running parameters: cadence, ground contact time, stride length, and vertical oscillation. The fitness watch was equipped with a motion sensor (gyroscope or accelerometer) and an optical sensor for measuring heart rate. It could also track the user's position during running and measure the distance using a Global Navigation Satellite System (GNSS).[30] To improve the accuracy of the watch, it is necessary to input personal data such as gender, weight, height, and the preferred side of the watch into Garmin's algorithm to provide accurate data for the users. To retrieve data from the fitness watch, we can utilize the software programs available on mobile devices (such as Garmin Connect), computer applications (such as Garmin Express).

Walker view treadmill and F-sensors

The Walker View Treadmill (TecnoBody®, Bergamo, Italy) is equipped with a 3D Camera for motion capture (model Kinect v2, Microsoft; acquisition frequency 30 Hz) designed for applications in sports medicine, rehabilitation, and gait analysis. It features foot sensors (F-sensor) with a full-scale accelerometer and gyroscope (frequency 100 Hz), along with a sensitized belt containing eight load cells (force platform) with a load range of 30-150 kg. The treadmill's integrated software, TecnoBody Management System from Bergamo, Italy, facilitates the real-time analysis of spatiotemporal parameters such as ground contact time, cadence, left and right step length, and vertical oscillation.[31, 32]

The Walker View treadmill requires personal data input such as gender, weight, height etc. for calculating parameters via software and algorithms. Subsequently, it generates a comprehensive report. For example, vertical oscillation involves detecting anatomical markers and uses the displacement of these markers and/or flight time data from F-sensors to calculate using the formula listed below.[33]

$$\text{Vertical oscillation} = 1/8 \times 9.81 \times \text{flight time}^2$$

Procedures

Participants preparation

Before testing, runners were required to wear a fitness watch on their habitual hand and an accelerometer on their pants (see Figure 1). F-sensors were placed on the runner's shoes at the midfoot area and the long side of the sensors were placed parallel to the longitudinal axis of the foot to detect the running parameters (see Figure 2). Next, the researcher explained the running process such as how to start and stop the watch, how to safely stop the treadmill, and made it clear to always run at the center area of the treadmill.

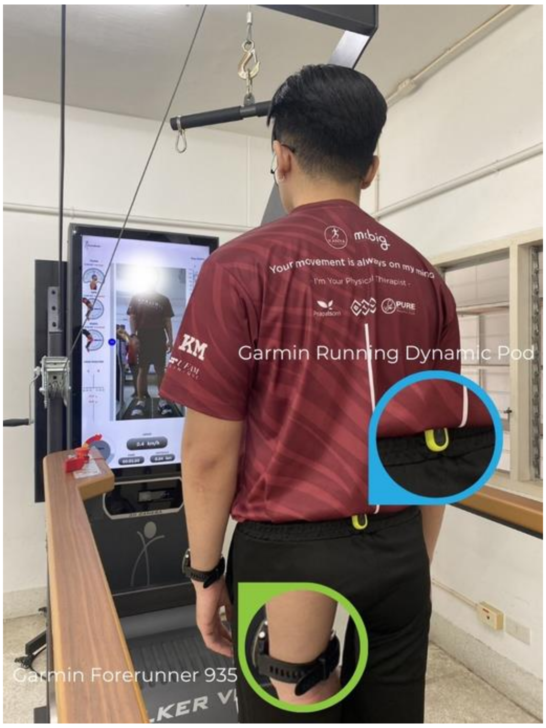

Figure 1 The fitness watch (Garmin forerunner 935) was worn on the habitual hand, and the accelerometer (Garmin Running Dynamics Pod) was attached to the pant.

Figure 2 Placement of the F-sensor on the Runner's Shoes.

Running test

The running protocol comprised three distinct sessions: a familiarization session, a rest session and a two-minute running session. Before the running session, runners were required to familiarize themselves with their habitual speed for about 30 seconds. Following the familiarization session, runners transitioned to a rest period lasting 1 or 3 minutes before commencing the subsequent running session. During a two-minute running session, the treadmill gradually speeds up to the target running speed for each participant in the ramp-up session. Following this, runners entered the two-minute running protocol, concluding with a ramp-down session as shown in Figure 3.

Statistical analysis

This study was designed to assess concurrent validity. For all statistical analyses, we employed IBM SPSS Statistics version 26.0, developed by IBM in Armonk, New York. This study used a two-minute running session to calculate the validity of fitness watch synced with accelerometer compared to the walker view treadmill. Descriptive statistics were used to analyze anthropometric data such as age, gender, and running speed. For validity, an ICC (3,1) was calculated to compare all parameters measured by fitness watch and accelerometer compared with measurements obtained by walker view treadmill. The ICC values below 0.50 indicate poor validity, between 0.5 and 0.75 moderate validity, between 0.75 and 0.9 good validity, and any values above 0.9 suggest excellent validity.[34] Furthermore, a Bland-Altman plot was conducted to show the variations in parameters between the fitness watch synchronized with the accelerometer and the walker view treadmill, allowing for the calculation of the limit of agreement (LOA) and bias. The mean, standard deviation, minimum, and maximum values for each running parameter were obtained from the fitness watch synced with accelerometer and walker view treadmill.

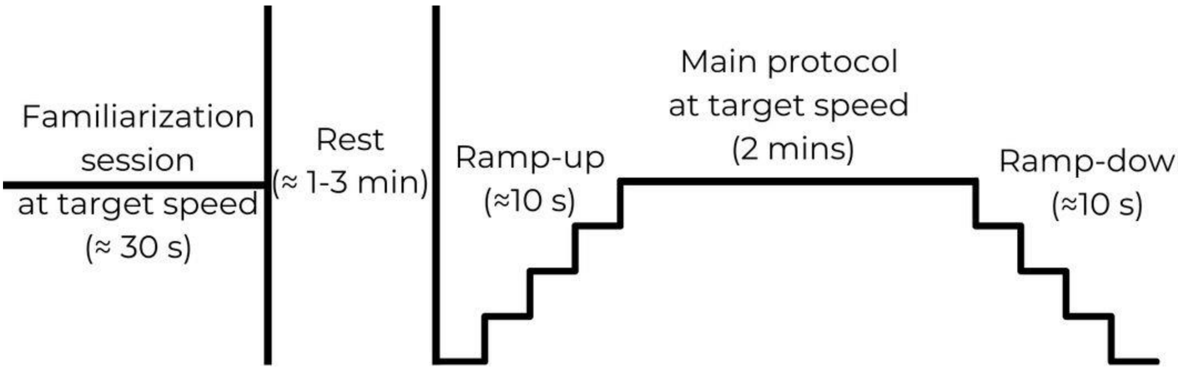

Figure 3 Procedures of Running Test.

Results

The validity of the running parameters measured using a fitness watch synced with accelerometer was examined among thirty-four active runners. Runner's characteristics are shown in Table 1.

Table 1 Characteristics of Runners (Mean ± SD and Range).

	Runners (N=34)	
	Mean ± SD	Range
Age (years)	38.9 ± 6.8	22.0- 48.0
Gender (M : F)	20 : 14	
Weight (kg)	64.2 ± 10.6	49.0 – 82.0
Height (cm)	168.6 ± 8.4	154.0 – 183.0
Body Mass Index (kg/m^2)	22.4 ± 1.8	20.4 – 26.8

Runners ran in a two-minute session to measure the running parameters, including cadence, ground contact time, stride length, and vertical oscillation. The average running speed was 11.6 ± 3.1 kilometers/hour. The minimum and maximum running speeds were 8 and 20 kilometers/hour, respectively.

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Table 2 shows that cadence measured from both devices was the same (180 steps/minute) and the ICC (3,1) was 0.99. Similarly, ground contact time measured from walker view treadmill and fitness watch were almost the same (0.23 and 0.24 seconds, respectively) and the ICC (3,1) was 0.94. With fitness watch, stride length was 1.01 meters when compared with walker view treadmill, stride length was 1.10 meters, therefore the difference was 0.09 meters. The ICC (3,1) was 0.86. Lastly, vertical oscillation measured by fitness watch synced with accelerometer was 8.80 centimeters and always overestimated (see Table 2 and Figure 4) when compared with walker view treadmill (5.60 centimeters). ICC (3,1) was 0.80. There is also the Bland-Altman plot, with two devices shown at the 95% confidence level of limits of agreement (LOA) in Figure 4. In the context of concurrent validity, 34 data points fall within the 95% limits of agreement (LOA) for cadence, demonstrating excellent validity (ICC = 0.99). Additionally, nearly 34 data points align with the ICC values for ground contact time, stride length, and vertical oscillation (ICC = 0.94, 0.86, and 0.80, respectively). Notably, outlying data points indicate lower levels of validity. Furthermore, minimal bias, close to zero, suggests that parameters measured from both devices (cadence, ground contact time, and stride length) are nearly identical. However, vertical oscillation exhibits a positive bias (3.20), indicating that measurements from fitness watches synchronized with accelerometers consistently yield higher values compared to those obtained from the Walker view treadmill.

Table 2 Validity of Spatiotemporal Parameters Measured by a Fitness Watch Synced with an Accelerometer, Compared to Walker View Treadmill.

Spatiotemporal parameters	Walker view Treadmill (mean ± SD)	Watch with Accelerometer (mean ± SD)	ICC [95% CI]	Bias	95% LOA
Cadence (step/min)	180±11.66	180±11.57	0.99 [0.99, 1.00]*	-0.12	[-1.28, 1.04]
Ground contact time (s)	0.24±0.04	0.23±0.03	0.94 [0.88, 0.97]*	0.01	[-0.02, 0.04]
Stride length (m)	1.10±0.25	1.01±0.17	0.86 [0.72, 0.93]*	0.09	[-0.20, 0.38]
Vertical oscillation (cm)	5.60±1.16	8.80±1.79	0.80 [0.59, 0.90]*	3.20	[0.75, 5.62]

Note: *Statistical significance, $p<0.05$, ICC = intraclass correlation coefficient; LOA = limit of agreement

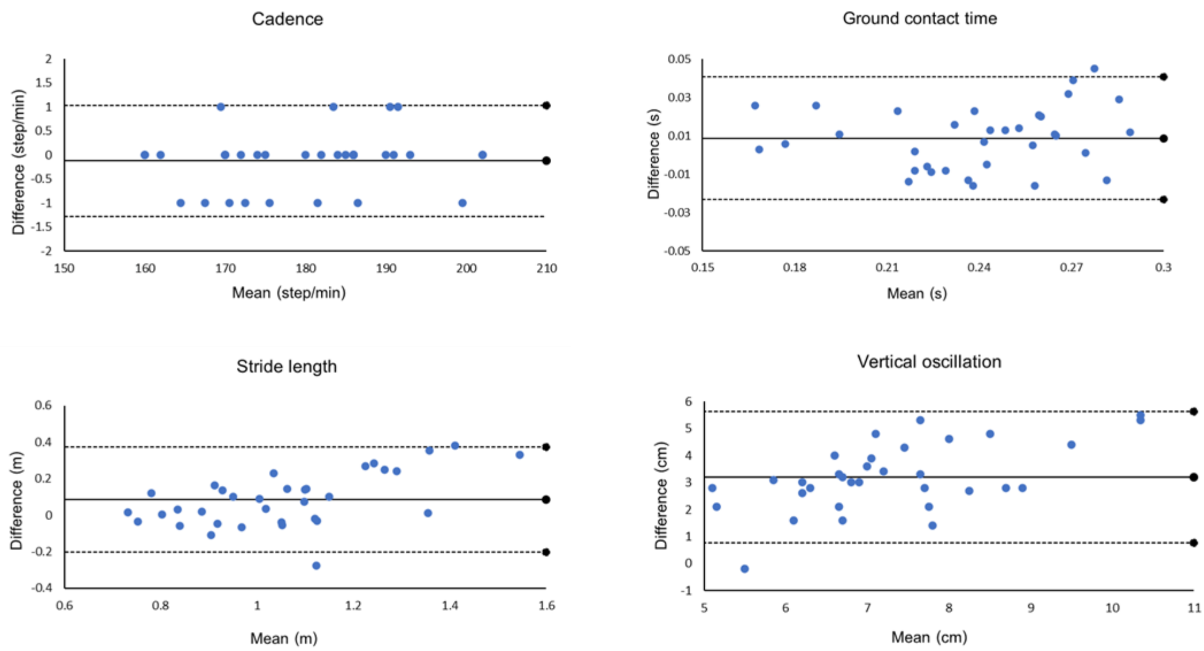

Figure 4 Bland-Altman Plots Comparing Spatiotemporal Running Parameters: Cadence (top Left), Ground Contact Time (Top Right), Stride Length (Bottom Left), and Vertical Oscillation (Bottom Right), as Measured by a Fitness Watch Synced with an Accelerometer versus a Walker View Treadmill.

Discussion

To indicate the levels of the validity of running parameters, a fitness watch synced with accelerometer was tested by comparing it with the walker view treadmill as a gold standard. Our results show excellent validity of cadence (ICC = 0.99) and ground contact time (ICC = 0.94) and good validity of stride length (ICC = 0.86) and vertical oscillation (ICC = 0.80). Furthermore, Bland-Altman analysis revealed that most of the data were within the limits of the agreement (LOA), indicating that the measured parameters were consistent across the two devices. However, only vertical oscillation measured by fitness watch synced with accelerometer was always overestimated when compared to the walker view treadmill.

Regarding excellent validity of cadence (ICC = 0.99) and ground contact time (ICC = 0.90). For cadence, a plausible explanation lies in the motion sensor embedded in fitness watches, which captures arm swings directly corresponding to leg steps during running. Thus, this motion sensor in fitness watches serves as a valid measure for assessing cadence. This finding aligns with Adams and colleagues (ICC = 0.93), affirming that motion sensors in the fitness watches when worn on the alongside an accelerometers, accurately depict cadence in steps per minute during running.[25] Regarding ground contact time, our results demonstrate excellent validity (ICC = 0.90). This validity arises from the synergy between fitness watches and accelerometers, which incorporate both accelerometers and gyroscopes. These sensors meticulously track and measure time during the stance phase which is the duration when feet remain in contact with the ground during a run. Consequently, this parameter exhibits high validity. It was higher than previous studies which showed moderate validity (ICC = 0.75)[25]. Previous research measured ground contact time by fitness watch (Garmin Fenix 2 and HRM-run) compared with 3D motion while running on treadmill.[25] It is well known that 3D motion is highly precise and accurate. Therefore, a possible explanation could be that ground contact time values derived from force plates of walker view treadmill were time sequences (two minutes). Therefore, the values averaged around 200-400 steps. Ground contact time values derived from 3D motion with 8 cameras were averaged only from just a few steps using a smaller window for analysis. Both devices could be used as a gold standard. However, the method of selecting data to use or what data to analyze is an important consideration. Therefore, ground contact time in this study reported excellent validity.

This study showed good validity of stride length (ICC = 0.86) and vertical oscillation (ICC = 0.80). A possible explanation could be that the accelerometer and gyroscope components within running dynamic pod exhibit good to excellent validity for detecting stride length and vertical oscillation. There was no previous research that examined the validity of stride length derived from fitness watches and accelerometers compared with any gold standard device used while running. However, our findings were in line with a systematic review and meta-analysis study that investigated and reported good validity of stride length during walking.[28] Outdoor running might increase this accuracy due to the precision of the Global Navigation Satellites System (GNSS).[30] Lastly, in this study, the validity of vertical oscillation was less than other parameters. However, the ICC still indicated good validity (ICC = 0.80), aligning with findings from Smith et al (ICC = 0.86) who used the same accelerometer (running dynamic pod) compared with video analysis.[27] In a similar context, Adams et al showed excellent validity (ICC = 0.96) for vertical oscillation derived from a fitness watch synced with accelerometer compared to 3D motion.[25] Taken together, when compared with one camera, good validity was illustrated and when compared with eight camaras, excellent validity was confirmed. Therefore, without any doubt, vertical oscillation derived from this fitness watch and accelerometer illustrated good validity. However, vertical oscillation values from the fitness watch and accelerometer used in this study were mostly overestimated when compared with the walker view treadmill. A possible explanation could be the differences between data collected from both devices. Vertical oscillation from accelerometers is simply calculated as the differences in the position of the accelerometer that moves from the highest and lowest points in the vertical direction while running.[26] Conversely, vertical oscillation derived from walker view treadmill was calculated from many resources such as displacement of an anatomical landmark via camera known as center of mass, the flight time from foot sensors, and/or by another equation.[33] The exact details of this formula are proprietary algorithms. In addition, other factors could influence vertical oscillation such as the stiffness of belt and musculotendinous stiffness of runners, etc. Nevertheless, in this study, vertical oscillation still showed good validity (ICC = 0.80).

Limitations

First, as the level of validity of the running parameters depends on the brands and specifications of watches and accelerometers, these results may not apply to other brands, Second, some running parameters such as ground contact time, stride length, etc., derived from the fitness watch report as average values from both legs whereas those derived from walker view treadmills are reported as left and right leg. Lastly, there are always some errors when calibrating running distance on the treadmill. When the runner stopped the treadmill, the machine slowed down for a few seconds, but the treadmill reported the distance when the stop button was pressed. Runners always pressed the stop button on the watch during slow down as a safety precaution. This problem could be solved during outdoor running as the distances can be measured accurately using Global Navigation Satellites System (GNSS).

Applications

Due to good and excellent validity of four running parameters derived from this fitness watch and accelerometer, clinicians, trainers, coaches, and runners can use them as guides in exercise programs to improve progression in terms of biomechanical running either in performance or in rehabilitation. In addition, researchers can be confident enough to perform further investigations outside the laboratory in natural running environments. Lastly, if we have access to normative data for different classes of runners such as recreation, novice, amateur, national elite, and international elite, we can strategically adjust training parameters to enhance performance and reduce the risk of running-related injuries.

Conclusion

In this study, good (stride length and vertical oscillation) and excellent (cadence and ground contact time) validity of four running parameters have been confirmed by using a fitness watch synced with accelerometer compared with a walker view treadmill. To enhance running performance, considering utilizing fitness watches synced with accelerometers as valuable tools for monitoring and assessing changes in running parameters daily.

Conflict of interest

The authors declare no conflict of interest.

Funding

This research has been partially funded by the Faculty of Associated Medical Sciences, Chiang Mai University.

Acknowledgements

The authors express gratitude to all runners and acknowledge the funding provided by the Faculty of Associated Medical Sciences, Chiang Mai University.

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