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Long term conditions

An observational study to evaluate the within-day reliability and concurrent validity of 2-minute walk test (2MWT) and 10-metere walk test (10MWT) in healthy individuals while wearing a mask.

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Keywords: within-day reliability, concurrent validity, wearing a surgical mask, 2-minute walk test, 10-meter walk test

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Abstract

Background

Exercise tests are widely used to prescribe exercises for patients with cardiorespiratory conditions and assess impact of treatments. The 2-minute walk test (2MWT) and 10-metre walk test (10MWT) are common assessments of functional exercise capacity. The COVID-19 pandemic resulted in people wearing masks (commonly surgical masks) to reduce infection. However, the validity and reliability of 2MWT and 10MWT wearing a mask is unknown and further research is required.

Aim

To assess the within-day reliability and concurrent validity of the 2MWT and 10MWT in healthy individuals wearing a surgical mask.

Design and Setting

Observational study, in a university setting

Methods

All participants completed three tests of 2MWT and 10MWT wearing a surgical mask (on one day) and one test without a mask (on a separate day) within one week. Oxygen saturation and heart rate were measured using pulse oximetry and the Borg scale assessed dyspnoea. Statistical analyses included: intraclass correlation coefficients (ICC) for within-day reliability of mask-wearing during three tests and Pearson's coefficient for concurrent validity correlated tests with a surgical mask and without a mask (the gold standard).

Results

15 people, mean (standard deviation) age 26 (2) years were included. The 2MWT and 10MWT (with mask) had excellent within-day reliability (ICC =0.823, 0.920 respectively). Both the 2MWT and 10MWT with and without a mask were highly correlated (r = 0.815, 0.943 respectively, p<0.01).

Conclusions

The results showed excellent within-day reliability and concurrent validity of 2MWT and 10MWT with a surgical mask in healthy individuals. Further research in clinical populations is needed.

INTRODUCTION

Exercise tests are widely used to prescribe exercises for patients with cardiorespiratory conditions such as chronic obstructive pulmonary disease (COPD) and assess impact of treatments. The cardiopulmonary exercise test (CPET) is the gold standard for maximal exercise testing but is difficult and expensive to administer.[1] Consequently, sub-maximal exercise tests, such as walking tests, are useful due to their ease and limited cost. The 6-minute walk test (6MWT), 2-minute walk test (2MWT) and 10-metre walk test (10MWT) are now widely used in clinical practice.[2] Although the validity and generalisability of the 6MWT have been well established, some patients have insufficient en-

durance or are unable to walk for 6 minutes. Therefore, 2MWT and 10MWT are efficient alternatives in clinical practice, where time and equipment are often limited. The 2MWT has been measured with intragroup retest reliability of 0.82,[3] and Leung et al.[4] also demonstrated high retest reliability for the 2MWT ($r = 0.999$; $p < 0.05$). In addition, Chan and Pin[5] found strong reliability (ICC = 0.95 - 0.99) and validity (r = 0.89 - 0.92) for the 10MWT in frail older adults, while Marques et al.[6] demonstrated high intra-rater reliability for the 10MWT in older patients with COPD (ICC = 0.903). Previously a high correlation was found between 2MWT and 6MWT (r = 0.937),[4] and a moderate correlation between 10MWT and 6MWT (r=0.449) ($p<0.05$).[7] This shows that the 2MWT and 10MWT are reliable and valid tests for assessing exercise capacity.

Most studies of exercise capacity are performed without wearing a mask. However, since 2020, the highly contagious nature of the COVID-19 pandemic resulted in the common use of masks to reduce infection risk. Surgical masks were widely used due to their low cost and availability. A rapid review has shown that wearing surgical masks reduced community transmission from COVID-19 because the face-mask could prevent the spread of coarse droplets and fine aerosols.[8] However, wearing surgical masks while walking on a treadmill has shown increased respiratory and heart rate, which may affect walking speed and endurance.[9] Additionally, mask-wearing may enhance resistance to inspiration and breathing and increase respiratory work.[10]

Shaw et al.[11] showed that wearing a surgical mask did not affect exercise performance in healthy subjects. Salles-Rojas et al.[12] found a strong correlation between 6MWT results with and without wearing a mask in healthy individuals ($r = 0.91$, $p < 0.001$). Several studies have shown no significant difference between the results of 6MWT with and without facemasks.[13,14] However as reliability and validity are different concepts concerning consistency and accuracy of the measurement, these must be established before use during exercise testing.[15] There have been no studies investigating the reliability and validity of the 2MWT and 10MWT wearing surgical masks. This study included healthy individuals to avoid any potential risks to patients, which is necessary before testing in people with cardiorespiratory conditions. The aim was to assess the impact of mask-wearing on within-day reliability and concurrent validity on healthy individuals.

OBJECTIVES

The objective of this study was to assess the within-day reliability of the 10MWT and 2MWT wearing a surgical mask (a cut-off of ICC>0.75 was used to indicate excellent reliability),[16] and the concurrent validity of the 10MWT and 2MWT with a surgical mask (correlation coefficient >0.70 was used to indicate good validity ($p<0.05$)).[17]

METHOD

STUDY DESIGN

In this observational study, all participants completed three tests of 2MWT and 10MWT wearing a surgical mask (on one day) and one test without a mask (on a separate day) within one week.

SETTING AND SAMPLE SIZE

Healthy individuals from Cardiff University were recruited from September to November 2022.

Sample size was based on the reliability analysis: to achieve good reliability, based on an ICC of 0.75, $\alpha = 0.05$, power set to 80% and R0 set to zero were used according to guidance.[18] According to guidance, a minimum of 11 participants were required. However, the calculation values were derived from a minimum sample size and there was a risk of data loss and participants dropping out midway, needed to consider recruiting an additional 20% of participants.[18] Therefore, 15 participants were recruited for this study.

The recruitment advertisements were shared on WhatsApp and Twitter and included inclusion/exclusion criteria, participants' requirement and contact details of the researcher. Interested participants emailed researchers, who responded by sending a participant information sheet.

INCLUSION AND EXCLUSION CRITERIA

For the safety of the participants and to ensure research completion, inclusion and exclusion were devised (Table 1). To ensure that potential risks were reduced, the Physical Activity Readiness Questionnaire (PAR-Q) was completed by each participant.[19] All subjects provided informed consent. This study was approved by the School of Healthcare Sciences Cardiff University Research Ethical Committee (No. REC904).

ASSESSMENTS

Baseline data included age, gender, height (SECA Leicester portable NS2030), weight (SECA Scales ETEKCITY 817915023259), and BMI (Kgm^2). A finger probe oximeter (ChoiceMMed MD300-D) recorded heart rate, and peripheral oxygen saturation before and after the tests, the modified Borg scale assessed dyspnoea, (Borg CR10 scale).[20] These are in line with previous work, to ensure the safety and recovery of the participants.

THE 2MWT PROTOCOL

Participants were asked to walk back and forth as far as possible on a flat 10m route for 2-minutes, in line with technical standards.[3] A 10-metre track was acceptable according to Beekman et al.[21] The researcher asked the participants to do their best during the 2MWT. The total distance walked by the 2MWT was recorded for each test.

Table 1. Inclusion and exclusion criteria

The inclusion criteria:	The exclusion criteria:
• Healthy adults aged 18-60 years from Cardiff University • Able to speak English. • Able to walk on the flat for 2 minutes. • Adults who agree to wear a surgical mask for whole test process	• Have current lower limb musculoskeletal disorders e.g., knee orthopaedical problems that limit the ability to walk. • Neurological conditions that affect walking, e.g., spinal cord injury affecting lower limb function • History of cardiopulmonary disease and cardiopulmonary symptoms that potentially affect the walking test, e.g., heart attack within the past month, severe uncontrolled hypertension, dizziness. • Adults who are exempt from wearing a surgical mask due to underlying conditions e.g., allergic to medical masks or had severe breathing difficulties when wearing a mask. • Have symptoms of covid-19 within two weeks. • Screened by PAR-Q questionnaire with "Yes" to one or more questions.

Table 2. 2MWT and 10MWT protocols

	2MWT and 10MWT	Day 1	Rest days	Day 7
Reliability (with mask)	Test 1	X		
	Test 2	X		
	Test 3	X		
Validity test (no mask)	Test			x

THE 10MWT PROTOCOL

The participants walked on a flat 10m route using standardised instructions.[22] The assessor recorded the time to complete the test using a stopwatch. Walking speed was calculated as distance/time, with walking speed used for analysis as it is a valid, reliable, and sensitive assessment of motor function.[23]

Participants performed three tests of the 2MWT and 10MWT, wearing a 3-layer surgical mask (Wecolor B0875S5TWF) to assess within-day reliability. Each test was separated by a 30-minute rest period to avoid participant fatigue as recommended by Eiser et al.[24] to ensure participants are recovered. Within one week, the 2MWT and 10MWT were completed without a mask (Table 2). This result was used as the gold standard to assess concurrent validity by comparing it with data from previous mask-wearing.

STATISTICAL ANALYSIS

Data entered was analysed using version 27.0 of the Statistical Package for Social Sciences (SPSS). Descriptive analysis of demographic data was reported as mean, standard deviation (SD), and range. The Shapiro-Wilks tested normality, $p > 0.05$, indicating that the 10MWT and 2MWT data followed a normal distribution.[25]

Within-day reliability was analysed for the three mask-wearing tests (test 1, test 2, test 3), using a two-way mixed intraclass correlation coefficient (ICC), ICC > 0.75 indicating excellent reliability.[16]

To assess validity, data from the third test of the reliability study wearing a mask were correlated to results without a mask (gold standard) for both 2MWT and 10MWT. The third test of the reliability assessments was used to ensure participants were familiar with the procedures and to reduce errors. A scatter plot was generated, and the correlation coefficient (r) was calculated using Pearson's coefficient[26,27] $r > 0.7$, indicating a strong correlation.[17] Bland-Altman plots (B&A) with 95% limits of agreement (LOA) were employed to illustrate absolute differences and identify systematic bias and outliers.[28]

RESULTS

A total of 15 subjects (53% males and 47% females) were included. Mean (SD) age was 26.0 (1.7) years, and BMI was 22.7 (2.5) Kg/m^2 (Table 3). Baseline heart rate, SPO_2, and Borg scores before and after the participants' 10MWT and 2MWT were all in the normal range.

WALKING DISTANCE (METRES) AND WALKING SPEED(M/S)

Table 4 shows descriptive statistics of walking speed and duration in the 10MWT and 2MWT with and without wearing masks.

For the reliability data: the mean walking speed for 10MWT results were similar, ranging from 1.3 (0.13) to 1.5 (0.2) m/s and the 2MWT range was 179.3 (16.2) to 183.7 (18.2) m. For the validity study, the 10MWT reliability Test 3 (with mask) and no mask were similar both 1.45 (0.2) m/s and 2MWT reliability Test 3 (with mask) was 183.7 (18.2), similar to no mask 187.1 (16.5) m.

RELIABILITY OF WEARING A MASK 10MWT AND 2MWT

The within-day reliability analysis for 10MWT was ICC 0.92, and for 2WMT was 0.823. This indicated that the 2MWT and

Table 3. Demographic descriptive data at baseline

Sample size=15	Mean	Std. Deviation	Range
Age (years)	26.7	1.7	6
Height (m)	1.67	0.06	0.24
Weight (kg)	63.3	9.1	34.6
BMI (kg/m²)	22.7	2.5	9.9
HR (bpm)	81	10	41
Borg	0.13	0.23	0.5
O2 (%)	98.0	1.0	3.0

Kg = kilogram, m = meter, BMI = body mass index number, SD = standard deviation.
bpm = beat per minute, HR= Heart rate, O_2= oxygen saturations

Table 4. The descriptive data of walking test with and without a mask

Sample size=15	Mask test 1 mean (SD)	Mask test 2 mean (SD)	Mask test 3 mean (SD)	No Mask test1 mean (SD)
10MWT m/s	1.3 (0.1)	1.4 (0.2)	1.5 (0.2)	1.5 (0.2)

m/s = meter/second, SD = standard deviation, m= meter, s= second.

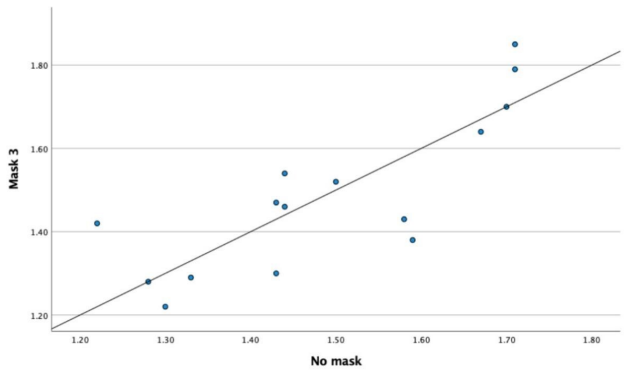

Figure 1. Scatter plot for 10MWT (Mask 3 and No mask)

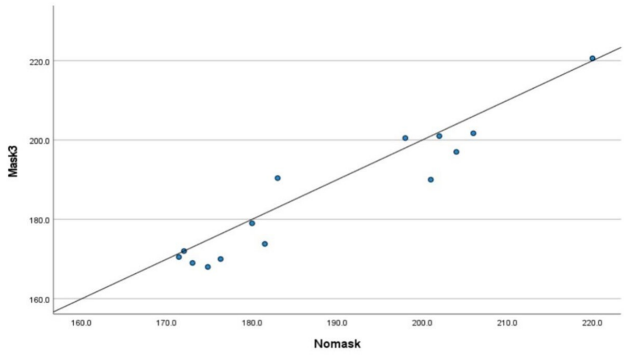

Figure 2. Scatter plot for 2MWT (Mask 3 and No mask)

10MWT had excellent reliability (ICC > 0.75) across 3 tests wearing a mask.[29]

VALIDITY OF WEARING A MASK 10MWT AND 2MWT

The scatter plots for 10MWT (Figure 1) show most of the data for mask and no mask were evenly distributed around the line of best fit. The number of points above, and below the reference line were almost equally distributed, demonstrating a positive linear relationship and a correlation between the two tests.

The scatter plots for 2MWT (Figure 2) show the data points were relatively evenly distributed on both sides of the reference line on the right and middle side of the line, demonstrating a positive linear relationship and a correlation between the two tests.

CORRELATION ANALYSIS

10MWT: For the 10MWT, the Pearson correlation coefficient r value for Test 3 (with mask) and no mask was 0.815 ($p < 0.001$), indicating an excellent and significant correlation as $r>0.75$.[22]

2MWT: For the 2MWT, Pearson's correlation coefficient of the Test 3 (with mask) and no mask was r=0.943 (p<0.01), indicating excellent correlation.[18]

BLAND-ALTMAN PLOTS FOR 10MWT AND 2MWT

The Bland-Altman plots for 10MWT validity (Figure 3) show a small difference of -0.03m/s between the mean of Test 3 (mask) and no mask suggesting good agreement, while the LOA (95% CI) ranged from -0.25 to 0.19m/s. One outlier in the plot exceeds the upper limit (0.19m/s), indicating a bias between the two tests.

The Bland-Altman plots for 2MWT validity (Figure 4) for Test 3 (mask) and no mask showed a mean difference between the two is -3.87 m, which indicated a small difference, and their LOA (95% CI) ranged from -16.17m to 8.45m, a relatively wide range. Most of the data points were scattered within this interval, while one outlier lies below the LOA, indicating some bias between the two tests.

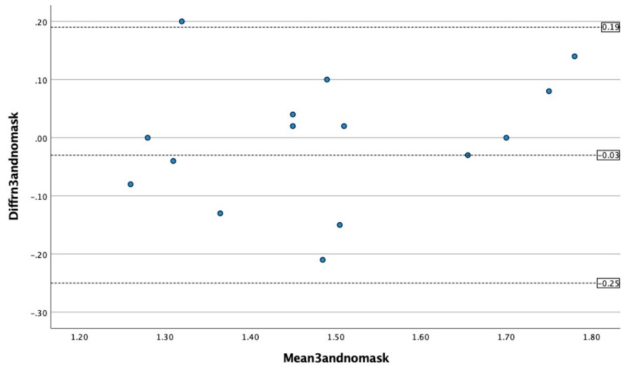

Figure 3. Bland-Altman plots for 10MWT (Mask 3 and No mask)

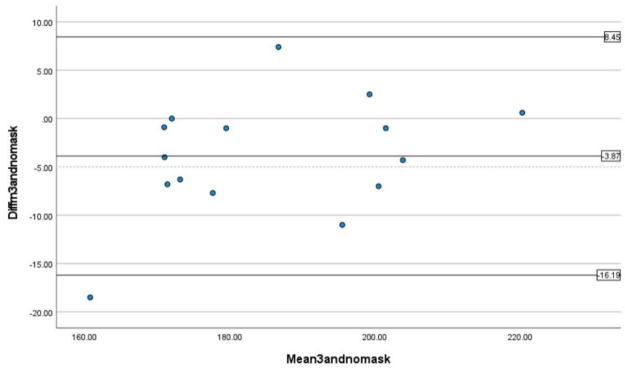

Figure 4. Bland-Altman plots for 2MWT (Mask 3 and No mask)

DISCUSSION

The aim of this study was to evaluate the within-day reliability and concurrent validity of the 10MWT and 2MWT wearing a surgical mask. The results showed the 2MWT with a surgical mask had excellent within-day reliability (ICC=0.92) and concurrent validity (Pearson's r value =0.943). The 10MWT with a mask also indicated excellent within-day reliability (ICC=0.823) and concurrent validity compared to those without a mask (Pearson's r-value = 0.815). In addition, the Bland-Altman plots for 10MWT and 2MWT validity showed good agreement, although some values were more dispersed, which may be attributed to the small sample size.[30]

To date there have been no published studies of the reliability and validity of 10MWT and 2MWT wearing a face mask, thus this study was compared to other research investigating mask-wearing with 6MWT and the reliability and validity of the 10MWT and 2MWT without a mask. Salles-Rojas et al.[12] found during the 6MWT, distances walked with or without a mask were significantly related in healthy people (r=0.91 (P< 0.001)). In 84% of participants, the difference in walking meters was within ±30m, and there was no difference in the degree of dyspnoea. These findings are consistent with the present study and the studies of Bohannon et al.[3] and Swiatek et al.[13] who found there was no difference in distance walked with mask or without mask. Leung et al.'s[4] study in COPD showed that 2MWT was highly correlated with 6MWT (r=0.937) and their ICC for reliability was (r=0.99, p<0. 005). This was similar to our ICC for 2MWT. Chan and Pin[5] also showed that the 10MWT without a mask had strong reliability (ICC = 0.95 - 0.99) and strong validity (r = 0.89 to 0.92) in frail older adults, which was consistent with our findings ICC 0.823 and r= 0.815. Despite differences in methodology, sample size and participants of the aforementioned studies, all studies concurred that the 10MWT and 2MWT without a mask were a reliable and viable instrument.

From a physiological perspective, Kyung et al.[31] argued that mask-wearing can influence airflow resistance and gas exchange. This is in contrast to Samannan et al.[32] who found that gas exchange was not significantly affected by the use of surgical masks. In a recent systematic review, Shaw et al.[12] examined the effects of wearing a mask on exercise and found that wearing a surgical mask or N95 mask did not affect exercise performance in healthy subjects. Dacha et al.[14] and Swiatek et al.[11] also showed that wearing a mask had no effect on functional ability (6MWT) but dyspnea was increased in healthy people. This suggests mask wearing may affect dyspnoea in the 6MWT. The 10MWT outcome is walking speed, whereas the 2MWT and 6MWT are more focused on assessing endurance.[33] The 2MWT and 10MWT are shorter than the 6MWT, which may account for the limited impact of wearing a mask. Wearing the mask for less time may have less impact than wearing it for 2 minutes, which explains the 10MWT had better reliability than 2MWT.

The overall findings suggested that wearing a mask for the 2MWT and 10MWT appears to be a valid and reliable exercise test in healthy people, which may reduce the risk of COVID-19 infections. However, the current study was limited to healthy young subjects (23-29 years), which may not be representative of a wider age group and different conditions. The increased airway resistance may have a greater physiological impact when using a face mask in patients with COPD or older people.[34] Therefore, further research is needed in other age groups and populations. The sample size was small but justified according to Bujang and Baharum,[18] however, this could limit generalisability.

CONCLUSION

The results of this study showed that wearing a mask during the 2MWT and 10MWT had excellent within-day reliability and concurrent validity. This suggests that mask-wearing does not impact 2MWT and 10MWT in healthy people. The results help to alleviate concerns about the use of surgical masks for walking tests and may increase the wider acceptance and use of masks. The results of the current study should be interpreted with caution as they are based on healthy adults, and the wearing of masks cannot be recommended for all exercise tests or populations. Before wearing a mask during the 2MWT and 10MWT, a larger and more diverse sample can be recommended, including cardiorespiratory conditions.

Key points

- Wearing a surgical mask for 2MWT and 10MWT had excellent within-day reliability.
- Wearing a surgical mask for 2MWT and 10MWT had excellent concurrent validity.
- The results help to alleviate concerns about the use of surgical masks for walking tests and may increase the wider acceptance and use of masks.

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ETHICAL APPROVAL

This study was approved by the Ethical Research Committee of the School of Health Research at Cardiff University (No. REC904). The authors declare that they have no known competing financial interests or personal relationships that would appear to influence the work reported in this article.

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