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First Author : M. Morris

Corr. Author : M. Morris

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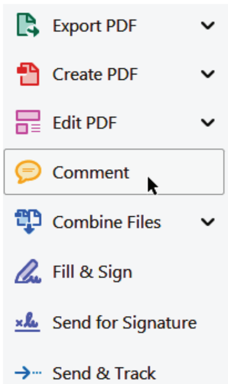

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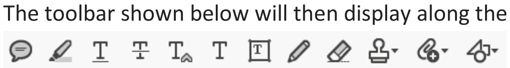

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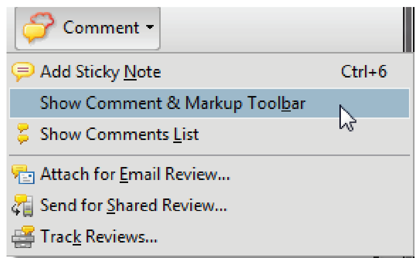

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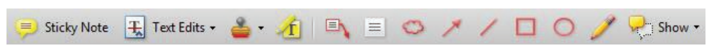

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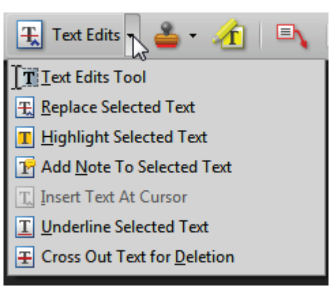

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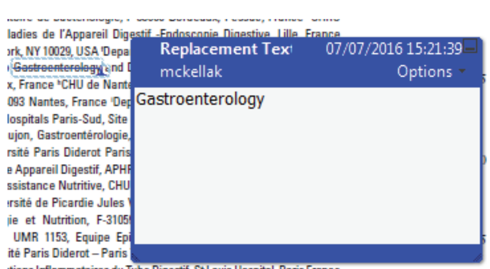

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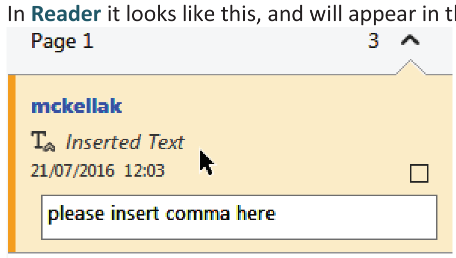

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Chester treadmill police tests as alternatives to 15-m shuttle running

M. Morris[1], E. Deery[1] and K. Sykes[2]

[1]Department of Clinical Sciences & Nutrition, University of Chester, Parkgate Road, Chester CH1 4BJ, UK, [2]Emeritus Professor of Occupational Health and Workplace Fitness, University of Chester, Chester, UK.

Correspondence to: M. Morris, Department of Clinical Sciences & Nutrition, University of Chester, Chester, UK. E-mail: m.morris@chester.ac.uk

Background Police officers require a specific level of aerobic fitness to allow them to complete personal safety training and specialist roles. Officers' aerobic fitness is assessed using the 15-m multi-stage fitness test (MSFT); however, due to the agility required and risk of injury, two alternative treadmill tests have been designed to predict four of the key minimum VO_2 criteria of 35, 41, 46 and 51 ml·kg^{-1}·min^{-1}.

Aims To investigate the validity and reliability of Chester Treadmill Police Walk Test (CTPWT) and Chester Treadmill Police Run Test (CTPRT).

Methods Seventy-eight UK police officers (18 females) completed the CTPWT (n = 53) or CTPRT (n = 35), or both, generating a total of 88 data sets. To assess reliability, 43 participants returned for a second visit (T2), to repeat the treadmill test.

Results Mean differences between predicted and actual VO_2 at 35, 41, 46 and 51 ml·kg^{-1}·min^{-1} were as follows −1.1, −2.1, −0.1 and −1.2 ml·kg^{-1}·min^{-1}. Despite a significant under prediction (p = 0.001), a minimum of 92% of participants were within 10% of target VO_2 at all levels. There was no significant difference between actual and predicted VO_2 in the CTPRT, at 46 ml·kg^{-1}·min^{-1} (T1 46.0 ± 1.4 or T2 45.1 ± 1.3 ml·kg^{-1}·min^{-1}). Similarly, there was no significant difference at 51 ml·kg^{-1}·min^{-1} (T2 50.5 ± 1.4 ml·kg^{-1}·min^{-1}). We observed no differences for gender or trial. Ninety-five per cent limits of agreement were at worst T1–T2 −0.25 ± 4.0 ml·kg^{-1}·min^{-1}.

Conclusions The CTPWT and the CTPRT provide a valid and reliable alternative to the 15-m MSFT.

Key words Exercise testing; fitness; fitness standards; occupational; police; predictive; treadmill test.

Introduction

Maximal oxygen consumption (VO_{2max}) is a commonly used measure of aerobic, or cardiorespiratory, fitness [1]. This measure has been associated with cardiometabolic health, mortality and athletic performance alike [2–6]. While it is desirable to measure VO_{2max} using online gas analysis, alternative tests have been developed to allow for the prediction of VO_{2max} without the use of specialized equipment or ergometery [7,8]. The use of these submaximal exercise tests to predict VO_{2max} has been widely investigated by researchers. Although there are noted limitations of submaximal exercise testing such as the reliance upon an accurate heart rate (HR), power output and VO_2 relationship, there are many submaximal protocols which are accepted to be an effective means of assessing cardiovascular fitness [1,9,10].

Similar to military personnel and firefighters [11], police officers are required to attend regular fitness testing to continue in operation. Following the Winsor report and based upon research carried out by Brewer [12], the College of Policing set out required standards of aerobic fitness for all operational officers (Table 1). To achieve the fitness required for personal safety training (PST), a $VO_{2\ max}$ of at least 35 ml·kg^{-1}·min^{-1} is necessary [12], with increasing requirements for specialist roles (Table 1). These requirements are assessed using a 15-m multi-stage fitness test (MSFT) which has been validated against the 20-m MSFT in an unpublished study [13]. This 15-m MSFT has also been compared to PST and specialist roles physiological demands [14] and to VO_{2max} in prior research [15]. However, the validity and reliability of shuttle testing to predict VO_{2max} have been questioned among specific populations [1,16]. Prior

AQ12 **Table 1.** Police fitness standards

Unit	Recommended standard (level: shuttle)	Estimated aerobic capacity[a] (ml·kg^{-1}·min^{-1})[b]
PST	5: 4	35
Marine police unit	5: 4	35
CBRN	5: 4	35
Method of entry	5: 4	35
Dog handler	5: 7	36
Mounted branch	5: 7	36
Police cyclist	5: 8	36
Police support unit	6: 3	37
Air support	6: 4	37
Police divers	6: 8	39
Marine police (tactical skills)	7: 2	40
Authorized firearms officer	7: 6	41
Armed response vehicle	9: 4	46
Dynamic intervention AFO	10: 5	51

AQ13 AQ14 Adapted from Brewer [12]. AFO, xxx; CBRN, xxx.
[a]Aerobic capacity must be at least this value in order to attain the shuttle standard.
[b]ml·kg^{-1}·min^{-1} values rounded to nearest whole number.

to participation, all officers are required to complete a medical questionnaire to ensure there are no medical contraindications such as musculoskeletal issues which may be aggravated by the twisting and turning associated with the MSFT. AQ9 For this reason, some forces have implemented an alternative fitness test (Chester Step Test, Astrand Cycle Test and Chester Treadmill Walk Test); however, the validity and reliability of the results may be questioned due to the lack of research investigating this. This paper will investigate the validity and reliability of Chester Treadmill Police Walk Test (CTPWT) [17] and Chester Treadmill Police Run Test (CTPRT) [18] in predicting four of the key VO_2 values laid out by Brewer [12] highlighted in Table 1. AQ10 These treadmill tests were developed by Sykes [17,18] to predict specified VO_2 AQ11 values (Table 1) using well-established ACSM metabolic equations [19].

Methods

A total of 78 UK police officers (18 females) volunteered to take part in the study (age: 42 ± 7 years; height: 1.8 ± 0.1 m; weight: 82.1 ± 15.2 kg; body mass index: 26.1 ± 3.5). The study aimed to recruit 40 participants per group (CTPWT and CTPRT) as per recommendations by Atkinson and Nevill [20]. All participants completed written, informed consent and health screening prior to taking part in the research project, which gained ethical approval from the University of Chester. Participants attended the University of Chester on two separate occasions having abstained from caffeine, alcohol and vigorous exercise for 24 h. Blood pressure and resting HR were recorded (Omron, Germany) along with body mass (kg) and stature (cm) (Seca, Germany). During each testing day, participants took part in the relevant treadmill test according to their self-reported performance of the 15-m MSFT (i.e. which level they are able to run to during the MSFT: 5:4, 7:6, 9:4 or 10:5) which participants were all familiar with. All participants were also familiar with treadmill walking and/or running prior to attending the University. Participants had a minimum of 24 h between testing days to allow adequate recovery time and repeatability was assessed within 2 weeks to limit the effect of time or changes to fitness. During exercise, HR (Polar, Finland), RPE [21] and oxygen consumption (VO_2) were AQ15 measured. Oxygen consumption was measured with online gas analysis (Metamax 3B, Cortex, Germany) and data were averaged to 10 s for subsequent analysis. While there are limitations associated with the use of time average data smoothing [22], 10-s averaging was employed to allow for future studies to directly compare with 15-m MSFT VO_2 data, for which 10-s averaging would be necessary to discern between shuttle levels. The use of this time-second averaging method is also supported by its use in similar studies [23]. Observation of the data by researchers showed no difference between the final two AQ16 10-s average periods recorded per stage. VO_2 values for the CTPWT and CTPRT (Sykes, 2015) were predicted using well-established ACSM equations [19].

Data were analysed using SPSS for Windows (version 22) and alpha was set at the 0.05 level. Normality of data was checked using Shapiro–Wilk statistic and descriptive statistics (mean ± SD) were computed. To investigate the difference between actual and predicted VO_2 values (validity), one sample *t*-tests were applied and independent *t*-tests to compare gender differences. The test–retest differences (reliability) were investigated using paired sample *t*-tests, 95% limits of agreement (LoA) (bias ± 1.96 × SD_{diff}), Bland–Altman LoA, typical error and intra-class correlation coefficient (Table 2).

Results

Fifty-three participants (15 females) completed up to Level 5 (35 ml·kg^{-1}·min^{-1}) on CTPWT once, with 30 (9 females) completing to this level twice, while 52 participants (15 females) completed up to Level 6 (41 ml·kg^{-1}·min^{-1}) on CTPWT once, with 28 (8 females) completing to this level twice (Table 3).

Thirty-five participants (9 females) completed up to Level 4 (46 ml·kg^{-1}·min^{-1}) on CTPRT with 13 (1 female) completing to this level twice, while 34 (1 female) participants completed to Level 5 (51 ml·kg^{-1}·min^{-1}) on CTPRT once, with 13 (1 female) completing to this level twice.

Table 2. CTPWT and CTPRT Protocols [17,18]

Level	Time (min)	Treadmill gradient	Predicted O_2 cost ($ml \cdot kg^{-1} \cdot min^{-1}$)[a]
CTPWT			
ACSM equation for walking: VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) = $(0.1 \cdot S) + (1.8 \cdot S \cdot G) + 3.5$ $ml \cdot kg^{-1} \cdot min^{-1}$ [24]			
Speed: 6.0 km/h			
1	0–2	0%	14
2	2–4	3%	19
3	4–6	6%	24
4	6–8	9%	30
5	8–10	12%	35
6	10–12	15%	41
CTPRT			
ACSM equation for running: VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) = $(0.2 \cdot S) + (0.9 \cdot S \cdot G) + 3.5$ $ml \cdot kg^{-1} \cdot min^{-1}$ [24]			
Speed: 10.4 km/h			
1	0–2	0%	38
2	2–4	2%	41
3	4–6	4%	44
4	6–8	5%	46
5	8–10	8%	51

S = speed in $m \cdot min^{-1}$; G = percent grade expressed as a fraction.
[a] $ml \cdot kg^{-1} \cdot min^{-1}$ values rounded to nearest whole number.

Table 3. Validity of CTPWT and CTPRT

Treadmill level (time)	Predicted VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	Trial 1: actual VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) (95% CI)	Trial 2: actual VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) (95% CI)
CTPWT			
Level 5 (10 min)	35	34.0 ± 1.8[a] (33.5–34.7)	34.3 ± 1.8[a] (33.7–35.0)
Level 6 (12 min)	41	39.0 ± 2.3[a] (38.4–40.0)	39.0 ± 2.5[a] (38.0–40.0)
CTPRT			
Level 4 (8 min)	46	45.9 ± .7 (45.6–46.5)	46.0 ± 1.4 (45.1–46.7)
Level 5 (10 min)	51	50.6 ± 1.2[a] (49.9–51.3)	50.5 ± 1.4 (49.6–51.4)

CI, confidence interval.
[a] Significant difference from predicted VO_2 p <0.05.

In Trial 1 of the CTPWT, there was a significant under prediction between recorded VO_2 and predicted VO_2 at 35 $ml \cdot kg^{-1} \cdot min^{-1}$ (34.0 ± 1.8 $ml \cdot kg^{-1} \cdot min^{-1}$; $p = 0.001$) and 41 $ml \cdot kg^{-1} \cdot min^{-1}$ (39.0 ± 2.3 $ml \cdot kg^{-1} \cdot min^{-1}$; $p = 0.001$) and in Trial 2 at 35 $ml \cdot kg^{-1} \cdot min^{-1}$ (34.3 ± 1.8 $ml \cdot kg^{-1} \cdot min^{-1}$; $p = 0.049$) and 41 $ml \cdot kg^{-1} \cdot min^{-1}$ (39.0 ± 2.5 $ml \cdot kg^{-1} \cdot min^{-1}$; $p = 0.001$), respectively. Despite this, 92% of participants (100% of females) in Trial 1 and 93% of participants (100% of females) in Trial 2 at Level 5 (minimum requirement for officers undertaking PST) were within 10% (i.e. equivalent to 1 metabolic equivalent [MET] = 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$) of the target VO_2 value of 35 $ml \cdot kg^{-1} \cdot min^{-1}$. All participants in Trial 1 and 82% of participants in Trial 2 (94% of females) at Level 6 were within 10% (4.1 $ml \cdot kg^{-1} \cdot min^{-1}$) of predicted values. There was no significant difference between males and females in Trial 1 at 35 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p = 0.628$), Trial 2 at 35 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p = 0.76$), Trial 1 at 41 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p = 0.88$) or Trial 2 at 41 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p = 0.9$).

The test–retest differences (reliability) of the CTPWT are summarized in Table 4, with comparisons across two trials. Paired t-tests revealed no significant differences between Trial 1 and Trial 2 at any level. Ninety-five per cent LoA between Trial 1 and Trial 2 were as follows for 35 and 41 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively: −0.25 ± 4.0 $ml \cdot kg^{-1} \cdot min^{-1}$ and 0.15 ± 2.8 $ml \cdot kg^{-1} \cdot min^{-1}$. Bland–Altman plots (Figures 1 and 2) showed acceptable LoA AQ17 between Trial 1 and Trial 2.

Actual VO_2 and predicted VO_2 were significantly different ($p < 0.05$) at 51 $ml \cdot kg^{-1} \cdot min^{-1}$ in Trial 1 of the CTPRT (50.6 ± 1.2 $ml \cdot kg^{-1} \cdot min^{-1}$). Despite this, 92% of participants in Trial 1 (100% of females) and all participants in Trial 2 at Level 4 were within 10% (4.6 $ml \cdot kg^{-1} \cdot min^{-1}$) of predicted values. Ninety-four per cent of participants (88% of females) in Trial 1 and 100% in Trial 2 at Level 5 were within 10% (5.1 $ml \cdot kg^{-1} \cdot min^{-1}$) of predicted values. There was no significant difference between actual and predicted VO_2 in the CTPRT, at 46 ml·kg^{-1}·min^{-1} during Trial 1 (46.0 ± 1.4 ml·kg^{-1}·min^{-1}) or Trial 2 (45.1 ± 1.3 ml·kg^{-1}·min^{-1}). Similarly, there was no significant difference at 51 ml·kg^{-1}·min^{-1} during Trial 2 (50.5 ± 1.4 ml·kg^{-1}·min^{-1}). There was no significant difference between males and females in Trial 1 at 46 ml·kg^{-1}·min^{-1} (p = 0.9), Trial 2 at 46 ml·kg^{-1}·min^{-1} (p = 0.6), Trial 1 at 51 ml·kg^{-1}·min^{-1} (p = 0.4) or Trial 2 at 51 ml·kg^{-1}·min^{-1} (p = 0.7).

The test–retest differences (reliability) of the CTPWT and CPTRT are summarized in Table 4, with comparisons across two trials. Paired t-tests revealed no significant differences between Trial 1 and Trial 2 at any level. Ninety-five per cent LoA between Trial 1 and Trial 2 were as follows for 46 and 51 ml·kg^{-1}·min^{-1}, respectively: 0.17 ± 2.8 ml·kg^{-1}·min^{-1} and 0.08 ± 2.3 ml·kg^{-1}·min^{-1}. Bland–Altman plots (Figures 3 and 4) showed acceptable LoA between Trial 1 and Trial 2.

Table 4. Test–retest differences of CTPWT and CPTRT across two repeated trials

Treadmill level (time)	95% LoA[a] (bias ± 1.96 × SD_{diff})	ICC	Typical error[a]
CTPWT			
Level 5 (10 min)	−0.25 ± 4.0	0.37	±1.33
Level 6 (12 min)	0.15 ± 2.8	0.89	±0.39
CTPRT			
Level 4 (8 min)	0.17 ± 2.8	0.28	±1.66
Level 5 (10 min)	0.08 ± 2.3	0.80	±0.51

AQ18 ICC, xxx.
[a]ml·kg^{-1}·min^{-1}.

Discussion

While our results show a statistically significant difference at some levels of the predictive treadmill tests, the magnitude of these differences are likely negligible in a practical setting with all mean differences between 0.06 and 2 ml·kg^{-1}·min^{-1}. Previous research examining treadmill protocols to predict VO_{2max} have reported error of between 11 and 18% and deem these levels to be unacceptable [23,25,26]. Drew-Nord *et al.* [27] report overestimations of between 1 and 2 METs with two predictive treadmill protocols, which would equate to around 3.5–7 ml·kg^{-1}·min^{-1} similar to findings by Zwiren *et al.* [9] and Tierney *et al.* [28] who report SEE of between 2.9 and 5.2 ml·kg^{-1}·min^{-1}. AQ20 This research reports variability much greater than shown within our study yet accepts tests as suitable for use, thus further supporting the findings of our study. Some evidence suggests that prediction equations overestimate the fitness of lower-fit individuals and under predict the fitness of higher-fit individuals [23,26]; however, our study did not investigate aerobic capacity of participants thus we are unable to comment on this. Confidence intervals of all levels do show a slight underestimation of

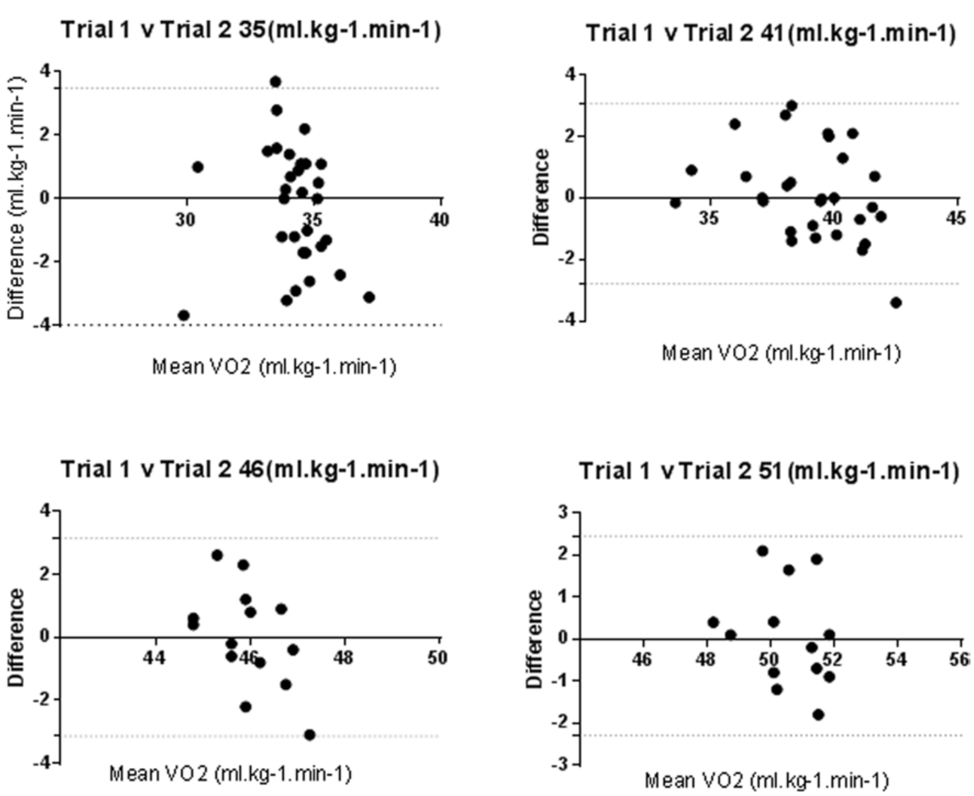

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Figure 1. Bland–Altman plots of reliability between trials.

VO_2 (Table 1); however, the magnitude of this is very low and arguably negligible in the practical setting. From the findings of this study, specialist units, who have specific VO_2 values to achieve, have been set individual time targets on the CTPWT (see Appendix Tables 6 and 7, available as Supplementary data at *Occupational Medicine* Online).

A limitation of the current study is the reliance upon tables provided by Brewer [12] (Table 1) which unfortunately gives no reference to confidence levels, or error margins, of estimated aerobic capacity. These values were devised by the equations provided by Roehampton University of Surrey [15] which similarly gave no indication of confidence levels. Therefore, the scarcity of information makes comparison of results somewhat difficult. However, research into the 20-m MSFT provides 95% LoA of ~6 ml [16], suggesting SD of ~3 ml, greater than ours (average SD of 1.6 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$). It could be suggested that these SD and LoA provided by Aandstad *et al.* [16] would be similar to Roehampton data [15], which would strengthen the findings and the predictive value of our tests to being able to predict VO_2 within these margins.

A particular strength of this study is that all participants were serving UK police officers, thus the findings can be generalized to the relevant population. Furthermore, the study included both male and female participants which prior similar research has commonly failed to address [23,26,27]. Interestingly, our analysis showed there was no gender bias for either the CTPWT or the CTPRT. Although great efforts were made, we did not have any black or minority ethnicity participants volunteer to take part in the study which weakens the generalizability of the findings. There are also accepted errors innate in the use of metabolic analysers [29]; however, the unit used within this study has been reported to be stable and reliable [30] and was used consistently among all trials to control for variation between units. Due to operational constraints not all officers were able to return for trial two testing, thus decreasing sample size of the reliability study; however, analysis of the data demonstrated excellent reliability across trials. Using LoA statistics, the CTPWT and CTPRT may over or under predict VO_2 values by between 2 and 4 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$. Typical error values between 0.51 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ and 1.66 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ further support the strength of the tests repeatability.

To conclude, while the statistical analysis of our study suggests there are statistical differences between predicted VO_2 values and actual VO_2 values, these variations are thought to be negligible within the practical setting and are much closer to predicted values than previous research has reported. Reliability data show that there is no need for a familiarization test for officers using either the CTPWT or CTPRT. Both the CTPWT and the CTPRT are therefore deemed as suitable alternative tests to the 15-m MSFT for any officer undertaking PST and for various specialist units (Appendix Tables 6 and 7, available as Supplementary data at *Occupational Medicine* Online).

Key points

- The CTPWT and CTPRT are valid tests to predict the VO_2 values set out by Brewer [12].
- The CTPWT slightly under predicted VO_2; however, the practical relevance is negligible and has minimal impact on classification of participants in attaining the required VO_2 for their roles.
- The CTPWT and CTPRT are reliable tests and a familiarization test is not deemed necessary in the practical setting.

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Competing interests

None declared.

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