Prediction of VO₂peak From the 20-m Shuttle-Run Test in Youth With Down Syndrome

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This study examined whether 20-m shuttle-run performance, sex, body mass index (BMI), age, height, and weight are associated with peak oxygen uptake (VO₂peak) in youth with Down syndrome (DS; n = 53; 25 women, age 8–20 years) and whether these variables can be used to develop an equation to predict VO₂peak. BMI, 20-m shuttle-run performance, and sex were significantly associated with VO₂peak in youth with DS, whereas age, height, and weight were not. A regression model included only shuttle-run performance as a significant predictor of VO₂peak; however, the developed prediction equation had low individual predictability. Therefore, 20-m shuttle-run performance alone does not provide valid prediction of VO₂peak in youth with DS. Sex, BMI, age, height, and weight do not improve the prediction of VO₂peak.

Individuals with Down syndrome (DS) are at high risk for mortality and morbidity (Day, Strauss, Shavelle, & Reynolds, 2005; Draheim, McCubbin, & Williams, 2002; Esbensen, Seltzer, & Greenberg, 2007). These findings may partially relate to their low levels of physical fitness (Fernhall et al., 1996; Horvat, Croce, Pitetti, & Fernhall, 1999; Pitetti, Climstein, Campbell, Barrett, & Jackson, 1992; Rimmer & Yamaki, 2006) and potentially to inadequate levels of physical activity (Draheim, Williams, & McCubbin, 2002; Frey, Stanish, & Temple, 2008; Shields, Dodd, & Abblitt, 2009). To improve this unfavorable profile of people with DS, physical activity promotion should start early in life (Rowland, 2007). Furthermore, effective...
individualized exercise programs should be designed based on sound assessment of peak oxygen uptake (VO$_{2\text{peak}}$). Laboratory assessment of VO$_{2\text{peak}}$ is typically unavailable to leaders of school- and community-based exercise programs, however. These professionals conveniently estimate VO$_{2\text{peak}}$ from endurance performance, using field-tests. Valid estimation of VO$_{2\text{peak}}$ in youth with DS may improve the quality of exercise programs in this population and may provide a valid field tool for measuring the effectiveness of these programs in improving aerobic fitness, thus contributing to lifelong health benefits.

The 20-m shuttle-run has been included in widely used batteries of physical fitness assessment in youth (Cureton, 1994; Winnick & Short, 1999), and it provides valid and reliable estimation of VO$_{2\text{peak}}$ in youth and adults without disabilities (Léger & Gadoury, 1989; Léger & Lambert, 1982; Liu, Plowman, & Looney, 1992; Stickland, Petersen, & Bouffard, 2003). An advantage of this test is that it allows physical activity professionals to concurrently test many participants. In addition, it follows a protocol of progressively increased intensity that mimics those of laboratory VO$_{2\text{peak}}$ measurement. It is also valid and reliable in youth with intellectual disabilities (Fernhall et al., 1998); however, only a small number of participants with DS was included in the validation study. The formula developed by Fernhall et al. (1998) included 20-m shuttle-run performance together with sex and body mass index and provides a valid prediction of VO$_{2\text{peak}}$ shown by cross-validation studies, including both individuals with intellectual disabilities (Fernhall, Pitetti, Millar, Hensen, & Vukovich, 2000) and persons without disabilities (Pitetti, Fernhall, & Figoni, 2002). Follow-up research, however, failed to cross-validate the developed prediction equation in 26 children and adolescents with DS (Guerra, Pitetti, & Fernhall, 2003). These findings suggest that an equation to predict VO$_{2\text{peak}}$ from 20-m shuttle-run performance in youth with DS may need to be specifically designed for this population. Furthermore, additional variables may improve the prediction. VO$_{2\text{peak}}$ in youth varies as a function of sex, adiposity, age, height, and weight (Krahenbuhl, Skinner, & Kohrt, 1985; Rowland, 2005; Rutenfranz et al., 1990); thus, these easy to measure variables may contribute to accurate estimation of VO$_{2\text{peak}}$ in youth with DS.

The purpose of the current study, therefore, was to examine the associations between VO$_{2\text{peak}}$ and 20-m shuttle-run performance, sex, body mass index (BMI), age, height, and weight in youth with DS. Furthermore, this study attempted to develop an equation to predict VO$_{2\text{peak}}$ from the aforementioned variables in this population. It was hypothesized that 20-m shuttle-run performance sex, BMI, age, height, and weight would collectively provide a valid prediction equation of VO$_{2\text{peak}}$ in youth with DS.

**Method**

**Participants**

Fifty-three individuals with DS (28 male and 25 female; 8–20 years-old; Table 1) participated in this study. Participants had mild-to-moderate intellectual disability. This classification was determined by qualified school professionals and subsequently reported to researchers by their parents or direct caregivers. Participants were free of pulmonary or cardiovascular disorders and none was smoking or...
taking medications that could affect the metabolic response to exercise. The study was approved by the Institutional Review Board. Written informed consent was obtained from participants with DS and their legal guardians.

**Procedures**

Participants attended two data collection sessions conducted at least three days apart. They refrained from food for at least four hours and from caffeine and exercise for 24 hr before each data collection session. During the first session, participants completed a peak exercise test, and during the second session, they completed the 20-m shuttle-run test. Before these sessions, all participants had attended at least one session of familiarization with the peak exercise and shuttle-run tests.

**Peak Exercise Test**

The peak exercise test was completed on a treadmill following a customized protocol. Starting speed ranged between 1.5 and 2.5 mph based on exercise performance during familiarization and starting grade was 0%. With speed constant, the grade was then increased by 2% every two minutes until it reached 12%. Thereafter, the treadmill speed was increased by 0.5 mph every minute while the grade was maintained at 12%. Participants were allowed to use the handrails when needed. Verbal encouragement was offered throughout the test, which was terminated when participants could no longer continue. This treadmill protocol is valid and reliable in eliciting peak cardiovascular and metabolic responses in people with intellectual disabilities, including those with DS (Fernhall, Millar, Tymesoson, & Burkett, 1990; Fernhall & Tymesoson, 1987; Pitetti, Millar, & Fernhall, 2000). Expired gases were collected throughout the test, using an open-circuit spirometry system (Vmax 29c, 2000).

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**Table 1** Mean and Standard Deviation (SD) for Age, 20-m Shuttle-Run Performance, and Anthropometric and Peak Physiologic Indicators of Youth With Down Syndrome

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Min—Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>14.5</td>
<td>2.9</td>
<td>9–20</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>146.5</td>
<td>12.0</td>
<td>120.0–178.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.6</td>
<td>17.6</td>
<td>24.5–109.3</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.9</td>
<td>5.1</td>
<td>16.2–37.4</td>
</tr>
<tr>
<td>Laps completed</td>
<td>8.6</td>
<td>4.2</td>
<td>3.0–22.0</td>
</tr>
<tr>
<td>VO₂peak (ml/kg/min)</td>
<td>27.0</td>
<td>5.4</td>
<td>17.3–39.3</td>
</tr>
<tr>
<td>RER peak</td>
<td>1.04</td>
<td>0.10</td>
<td>0.83–1.30</td>
</tr>
<tr>
<td>HR peak (bpm)</td>
<td>174.6</td>
<td>10.5</td>
<td>138–195</td>
</tr>
</tbody>
</table>

*Note.* BMI = body mass index; VO₂peak = peak oxygen uptake; RER peak = peak respiratory exchange ratio; HR peak = peak heart rate; Min = minimum; Max = maximum
SensorMedics, Yorba Linda, CA). The pneumotachometer and the gas analyzers were calibrated before each experimental session, using a 3-L calibration syringe and gases of known concentration, respectively. Heart rate was measured with a telemetry monitor (model 210, Polar, Finland). Heart rate and oxygen uptake were recorded in 20 s averages. The highest values for these variables obtained during the last stage were considered peak heart rate and VO\textsubscript{2peak}, respectively.

### 20-m Shuttle-Run Test

The 20-m shuttle-run test was completed on an outdoor tennis court in the morning hours (9 a.m. to 11 a.m.) and at or below an ambient temperature of 29 °C (85 °F). Testing followed the procedures set by widely-used fitness assessment batteries (Cureton, 1994; Winnick & Short, 1999); these procedures have been previously established as valid and reliable for youth with intellectual disabilities, including those with DS (Fernhall et al., 1998). The 20-m distance was marked with cones and painted stripes. Before testing, participants practiced the protocol several times. Testing commenced after participants demonstrated good running form and an understanding of the procedures. Thereafter, participants ran in groups of 2–6 while paced at a given speed by Prudential Fitnessgram tapes (Cureton, 1994) and by a researcher who ran alongside and offered verbal encouragement. During the first minute of the protocol, the 20-m distance was covered in 9 s; thereafter, the allotted time was decreased by 0.5 s every minute, allowing for a graded increase in speed. The test was terminated when the participant could no longer continue or could not keep up with the required speed for two laps. The number of laps completed by the participant was recorded for subsequent analysis.

### Data Analyses

The VO\textsubscript{2peak} (in ml/kg/min) measured with the treadmill exercise test was the dependent variable. Potential independent variables included the number of laps completed during the 20-m shuttle-run test, sex, BMI, age, height, and weight, which reportedly contribute to the variance in VO\textsubscript{2peak} in people with and without disabilities (Fernhall et al., 1998; Krahenbuhl et al., 1985; Rowland, 2005; Rutenfranz et al., 1990; Stickland et al., 2003). The associations between VO\textsubscript{2peak} and each of the potential independent variables as well as among all independent variables were examined with Spearman’s correlation coefficient to account for the nonparametric nature of sex and to ensure uniformity across variables. The variables that showed significant correlations with VO\textsubscript{2peak} were used to develop an equation that predicted VO\textsubscript{2peak}, using stepwise multiple linear regression (Tabachnick & Fidell, 2001). Before analysis, the assumptions of multivariate regression were confirmed following a previously suggested procedure (Tabachnick & Fidell, 2001). The prediction equation was then used to estimate the VO\textsubscript{2peak} for each participant. The agreement between the estimated and the actual VO\textsubscript{2peak} was further evaluated with a Bland-Altman plot (Bland & Altman, 1999). The alpha level was set at 0.05. Statistical analyses were performed with PASW Statistics 17.0 (SPSS Inc., Chicago, IL, USA).
Results

The mean values for age and anthropometric and physiologic characteristics of participants are listed in Table 1. Participants had moderate mean BMI. Participants had low VO₂peak and low performance on the shuttle-run test.

Table 2 shows a matrix of Spearman correlations among the dependent and potential independent variables. VO₂peak did not correlate significantly with age, height, or weight. In contrast, VO₂peak showed significant correlations ($p < .05$) with the number of laps achieved during the shuttle-run test, sex, and BMI. These variables were therefore used as independent variables in the regression model.

The stepwise regression model included only the number of laps as a predictor; sex and BMI did not enter the model. The number of laps significantly predicted VO₂peak ($p < .001$), but predictability was low; the model accounted for 23% of the variance in VO₂peak ($R^2 = 0.23$; Standard Error of Estimate = 4.8 ml/kg/min). The prediction equation developed was:

$$\text{VO}_2\text{peak (ml/kg/min)} = 21.68 + 0.62 \times \text{# of laps}$$

The mean error of agreement as determined by the Bland-Altman technique was zero (Figure 1); however, the difference between actual and predicted VO₂peak demonstrated large individual variability (95% CI: –9.3 to +9.3 ml/kg/min). Notably, as the plot shows, the developed prediction equation appeared over-predictive in participants with low actual VO₂peak and under-predictive in participants with relatively high VO₂peak.

Table 2 Matrix of Spearman’s Correlation Coefficients Among Peak Oxygen Uptake (VO₂peak), 20-m Shuttle-Run Performance (Laps), Sex, Body Mass Index (BMI), Age, Height, and Weight in Youth With Down Syndrome

<table>
<thead>
<tr>
<th>Laps</th>
<th>Sex</th>
<th>BMI (kg/m²)</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂peak 0.45*</td>
<td>–.29*</td>
<td>–.28*</td>
<td>0.03</td>
<td>0.22</td>
<td>–.03</td>
</tr>
<tr>
<td>Laps –.34*</td>
<td>–.15</td>
<td>–.12</td>
<td>0.20</td>
<td>0.43*</td>
<td>0.14</td>
</tr>
<tr>
<td>Sex –.06</td>
<td>0.35*</td>
<td>0.30*</td>
<td>–.38*</td>
<td>0.83*</td>
<td></td>
</tr>
<tr>
<td>BMI 0.53*</td>
<td>0.54*</td>
<td>0.72*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = significant correlation ($p < 0.05$)
Discussion

This study examined the degree to which 20-m shuttle-run performance, sex, BMI, age, height, and weight are associated with VO$_{2\text{peak}}$ in youth with DS and whether they can be used to develop an equation to predict VO$_{2\text{peak}}$. The main finding was that 20-m shuttle-run performance contributed significantly to the variance in VO$_{2\text{peak}}$ in youth with DS, but a prediction equation with shuttle-run performance as the only predictor had low individual predictability. Furthermore, sex, BMI, age, height, and weight did not improve prediction of VO$_{2\text{peak}}$.

The prediction of VO$_{2\text{peak}}$ from 20-m shuttle-run performance in participants with DS did not reach acceptable levels; the present regression model, which included only shuttle-run performance as predictor, explained only a small amount of variance in VO$_{2\text{peak}}$. Furthermore, as the Bland-Altman plot demonstrated, the 95% limits of agreement between the actual and the estimated VO$_{2\text{peak}}$ were wide, thus invalidating the prediction of individual scores from the developed formula.
For example, an individual with DS who completed 15 laps during the 20-m shuttle-run test would have an estimated VO_{2peak} of 31.0 ml/kg/min. Because of the large confidence interval, we could only state with 95% confidence that the actual VO_{2peak} would be between 21.8 and 40.3 ml/kg/min. Furthermore, the developed equation appeared over-predictive in those with lowest VO_{2peak} and under-predictive in those with highest VO_{2peak}. The physiologic causes of such systematic errors in prediction cannot presently be determined and should be studied directly. Collectively, although the mean VO_{2peak} was accurately predicted for the group, there was a very large error in individual prediction. These findings are in contrast to those of previous studies, showing that shuttle-run performance alone may provide valid and reliable prediction of aerobic capacity in youth and adults without disabilities (Léger & Gadoury, 1989; Léger & Lambert, 1982; Liu et al., 1992). These findings, however, are similar to those in the cross-validation study by Fernhall et al. (2000) showing that group prediction was adequate, but individual prediction of VO_{2peak} was not acceptable in youth with intellectual disabilities without Down syndrome. Therefore, it appears that, in addition to shuttle-run performance, more variables with explanatory power should be included in providing a meaningful prediction of VO_{2peak} for youth with DS. Although we considered sex, BMI, age, height, and weight for inclusion in the regression, these variables did not improve VO_{2peak} prediction in the current study.

Sex and BMI did not explain significant portions of the variance in VO_{2peak} in addition to that explained by shuttle-run performance. In contrast, previous research in youth with intellectual disabilities that included a small number of participants with DS found that sex and BMI, in addition to shuttle-run performance, offered acceptable prediction of VO_{2peak} (Fernhall et al., 1998). The present results may be due to the low associations of sex and BMI with VO_{2peak} in participants with DS. In addition, sex may share some variance in VO_{2peak} with shuttle-run performance and may thus have low unique contribution to VO_{2peak}. In support of this argument, sex correlated significantly with shuttle-run performance in the present participants and previous research has shown that sex is associated with endurance performance in people with DS (Vis et al., 2009). Similarly, although the association of BMI with shuttle-run performance was low and nonsignificant, it may still have lowered the unique shared variance between BMI and VO_{2peak}. Another explanation may relate to the fact that mean BMI was not high in the present participants and may not have varied enough as a function of VO_{2peak}. From a practical standpoint, sex and BMI do not appear to have the potential to improve the prediction of VO_{2peak} in youth with DS.

Similarly, age, height, and weight did not show significant associations with VO_{2peak} and were therefore excluded from the regression analysis. For weight, this was not surprising; its possible effect was accounted for by expressing VO_{2peak} as a function of weight. Similarly, although VO_{2peak} varies as a function of height in adolescents without disabilities (Rutenfranz et al., 1990), height was not significantly associated with VO_{2peak} in the present participants with DS. One explanation for this observation is that people with DS are relatively short and their small variance in height may have resulted in low correlation with VO_{2peak}. Furthermore, height significantly correlated with shuttle-run performance, sex, and BMI, indicating a low potential to contribute uniquely to the variance in VO_{2peak}. Age, however, would
normally be expected to correlate inversely with \( \text{VO}_2\text{peak} \) in the present participants who were 8–20 years old. This is because girls without disabilities show a decline in \( \text{VO}_2\text{peak} \) from 7 until 17 years of age and, although boys without disabilities show relatively stable \( \text{VO}_2\text{peak} \) during the same years, their \( \text{VO}_2\text{peak} \) declines thereafter (Krahenbuhl et al., 1985; Rowland, 2005). Recent cross-sectional data, however, show that people with DS do not exhibit the same significant decline in \( \text{VO}_2\text{peak} \) between ages 9 and 45 years (Baynard, Pitetti, Guerra, Unnithan, & Fernhall, 2008) as people without disabilities do (Talbot, Metter, & Fleg, 2000). One potential reason for this observation confirmed by the present results is that people with DS show very low \( \text{VO}_2\text{peak} \) values (Baynard et al., 2008; Fernhall et al., 1996; Pitetti et al., 1992); thus, further decline with age appears to be marginal. Therefore, age, height, and weight may not be useful predictors of \( \text{VO}_2\text{peak} \) in youth with DS.

**Implications**

The inability of the 20-m shuttle-run test together with other easily determined variables to provide valid prediction of \( \text{VO}_2\text{peak} \) in youth with DS is unfortunate. It is possible that the shuttle-run test may not be appropriate for youth with DS. Such possibility, however, should be evaluated carefully because this is a widely used test that has been proven successful with other populations. The quality of school- and community-based exercise programs for persons with DS may improve greatly by valid indirect assessment of \( \text{VO}_2\text{peak} \). Notably, persons with DS report that one of the barriers to exercise they experience is that the prescribed intensity of exercise programs is often too high (Heller, Hsieh, & Rimmer, 2004). Inappropriately prescribed high relative exercise intensity may partially be due to over-estimation of \( \text{VO}_2\text{peak} \). Accurate field-based measurement of aerobic capacity may allow exercise professionals to develop sound individualized exercise programs for persons with DS. Furthermore, accurate prediction of \( \text{VO}_2\text{peak} \) would allow for valid appraisal of the effect of exercise programs in this population. The 20-m shuttle-run, however, does not provide valid estimation of aerobic capacity in youth with DS, and no other field test has been shown to be a better predictor of aerobic capacity in this population.

**Suggestions for Future Research**

It is possible that shuttle-run tests may become valid in this population if additional variables, different from the present ones, are considered. One such variable is heart rate during the last stage or in early recovery from the shuttle-run. Individuals with DS show altered autonomic function (Fernhall & Otterstetter, 2003; Heffernan et al., 2005; Iellamo et al., 2005), likely contributing to their previously reported (Fernhall et al., 2001; Guerra, Llorens, & Fernhall, 2003) and presently confirmed low peak heart rates that in turn limit their \( \text{VO}_2\text{peak} \) (Fernhall et al., 2009). Heart rate during the last stage of the shuttle-run or early in recovery can be measured easily and may prove an acceptable surrogate for actual peak heart rate. Other potential predictors that may improve the accuracy of shuttle-run tests is a field measure of leg strength, which correlates with \( \text{VO}_2\text{peak} \) in youth with intellectual disability including those with DS (Pitetti & Fernhall, 1997) as well as a valid and
population-specific field-measure of body composition. These suggestions and the possibility that other field tests may provide accurate VO_{2peak} estimation in youth with DS should be examined empirically.

**Limitations**

In interpreting the present results, the following limitations should be considered. First, the low accuracy of the prediction equation and the failure of the regression model to include additional predictors may partially be due to limited sample size. The number of participants, however, was higher than that often employed in physiological and behavioral research in people with DS. Furthermore, previous research using a smaller sample size has shown acceptable prediction in youth with intellectual disabilities (Fernhall et al., 1998). Second, VO_{2peak} prediction may have been invalidated by error in the measurement of VO_{2peak} and shuttle-run performance due to motivational factors. Past research, however, has shown that both VO_{2peak} and shuttle-run tests are highly reliable in youth with DS (Fernhall et al., 1998; Pitetti et al., 2000).

**Conclusions**

In youth with DS, 20-m shuttle-run performance does not appear to provide accurate estimation of VO_{2peak}. Furthermore, sex, BMI, age, height, and weight do not improve the estimation of aerobic capacity from shuttle-run performance in this population. Future work must examine additional variables that may provide accurate field-based assessment of VO_{2peak} in youth with DS. Valid prediction of VO_{2peak} from field-tests may improve the quality of exercise programming for persons with DS.

**References**


