Title: Self-selected walking speed predicts ability to run following traumatic brain injury.

Running Title: Running following TBI

Corresponding Author
Dr Gavin Williams, Physiotherapy Department, Epworth Hospital.
89 Bridge Rd, Richmond, 3121, Victoria, Australia.
Ph: 613 9426 8727
Fax: 613 9426 8734
Email: gavin.williams@epworth.org.au

Authors
Dr Gavin Williams PhD, Epworth Hospital, Melbourne and Centre for Health Exercise and Sports Medicine, School of Physiotherapy, The University of Melbourne.

Dr Anthony G. Schache PhD, Department of Mechanical Engineering, University of Melbourne.

Professor Meg E. Morris PhD, School of Physiotherapy, The University of Melbourne.

Word count:
Manuscript: 3110
Abstract: 173

Disclosures
The authors have no disclosures of declarations of interest to report.

Acknowledgements
The authors wish to thanks Sean McGuigan for his assistance in preparing this manuscript.

Key words: Brain trauma, Gait disorders, Assessment, Rehabilitation, Running
Self-selected walking speed predicts ability to run following traumatic brain injury.

Abstract

Objective: To identify factors that predict running ability following traumatic brain injury (TBI), and to quantify performance thresholds for these predictors. Design: Cross-sectional cohort study. Participants: One hundred and fourteen people with TBI. Outcome Measures: Self-selected walking speed, the High Level Mobility Scale (HiMAT), postural stability (lateral centre of mass displacement), ankle power generation at push-off and quality of gait performance (Gait Profile Score). Results: All predictor variables were all strongly associated with the ability to run. However, only self-selected walking speed contributed significantly to the final result. Investigation of performance thresholds for self-selected walking speed indicated that following TBI, people who walk at speeds of 1.0 m/sec or higher are 16.9 times more likely of being able to run than for those who walk at speeds of less than 1.0 m/sec.

Conclusions: Self-selected walking speeds higher than 1.0 m/s greatly increase the likelihood of running following brain injury. The 1.0 m/s threshold, although slower than able-bodied self-selected walking speeds, may be an important indicator of the ability to run in this population.

Key words: Brain trauma, Gait disorders, Assessment, Rehabilitation, Running
Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability for adolescents and young adults, especially males. Mobility limitations are prevalent but surprisingly little is known about the effects of TBI on mobility, particularly for higher levels of mobility. Higher levels of mobility, such as the ability to run, are important for participation in a wide variety of social, leisure, sports and employment activities. Although no data exist for TBI, recent findings in younger people following stroke suggest that regaining the ability to run, even for short distances, is associated with a greater likelihood of successful return to work. If the ability to run is important for higher rates of societal participation, then at some point in the rehabilitation phase following neurological injury clinicians may be confronted with the decision of when it is safe for a patient to commence running.

Although walking and running are biomechanically similar, running has a flight or ‘no-contact’ phase where neither leg is in contact with the ground in contrast to walking where at least one leg is always in contact with the ground. Both require the efficient movement of the body over the base of support whilst generating adequate muscle power for forward propulsion. Running is the natural progression of walking when greater speed is required, yet the training of running following TBI raises many issues. Following TBI, balance and mobility problems are common and associated difficulties with impulsiveness, planning, insight and self-monitoring potentially place some people with TBI at greater risk of falling. In addition to these risks, when compared to walking, running is associated with faster and greater amplitudes of movement, reduced ground contact time and the introduction of a flight phase where neither foot is in contact with the ground. All these factors may heighten the risk of falling. Despite
the importance of high-level mobility and the ability to run for greater societal participation, few guidelines or recommendations exist for clinicians to use for deciding when it may be reasonable to assess running abnormalities, or when running training may be safe and effective to commence.

Several studies have found that postural control and balance are compromised, even in well recovered people following TBI.\textsuperscript{4-6} Recently, Williams & Morris (2011) reported a strong relationship between postural control and mobility in a group of 71 people with TBI.\textsuperscript{9} In this study the high-level mobility assessment tool (HiMAT),\textsuperscript{10} which includes a running item, was used as one of the outcome measures for mobility. Despite this strong relationship, analysis of the data demonstrated that static measures of balance could not be used to predict mobility performance. Another study by Williams et al. (2010)\textsuperscript{11} found postural instability was prevalent when walking at self-selected speeds in a group of 55 people with TBI, yet it did not prevent the majority from walking at faster speeds. Their results indicate that the slow gait speeds observed following TBI may be a result of reduced ankle power generation at push-off. Similar findings have been obtained in studies investigating participants with stroke.\textsuperscript{12,13} Further examination of the physical factors which predicted mobility outcome after six months of rehabilitation following TBI found that ankle power generation at push-off and quality of gait performance explained much of the variability in mobility outcome.\textsuperscript{14} Although postural control and muscle power generation are important for normal walking, the extent to which these factors limit higher level mobility tasks such as running has not yet been investigated.

Other factors that may predict ability to run include quality of gait performance and self-selected walking speed. The quality of gait performance may determine ‘readiness to run’
because how ‘normal’ someone looks when performing high-level mobility tasks is strongly related to physical performance. People who walk with a gait pattern which closely resembles that of able-bodied walking might be more likely to be able to run. Some limited evidence exists suggesting some people with neurological conditions may perform better on higher-level tasks such as walking or running at faster speeds, compared to relatively easier demands of self-selected walking. Despite these observations, two larger studies have found self-selected walking speed to predict higher-level activities such as outdoor and community mobility following stroke. It was demonstrated in these studies that a self-selected walking speed exceeding 0.8 m/s was associated with improved outdoor and community mobility. To date, the quality of gait performance and self-selected walking speed have yet to be examined as predictors of running in people with neurological conditions.

Although running is the natural progression of walking, simply asking a person with TBI to walk faster and faster until they may or may not be able to run is potentially dangerous. An alternative method for predicting running performance has been identified in several clinical measures of mobility. Hierarchically organized scales such as the Rivermead Mobility Index (RMI) and the HiMAT include a running item. The RMI was developed with Guttman scaling which orders the difficulty of the items on the scale. The HiMAT was developed with more advanced Rasch analysis techniques which, in effect, does a similar role as Guttman scaling in ordering the difficulty of mobility items. The content of the RMI and HiMAT vary, yet the hierarchical organisation may be useful in identifying which mobility task precede running in overall level of difficulty. The most difficult mobility item on the RMI which precedes running is the ability to walk up and down four steps. In contrast, the ability to negotiate a flight of stairs is considered relatively easy on the HiMAT which identifies
bounding (jumping forward from one leg to the other) as the most difficult task preceding running. Bounding was also identified in an earlier study as the strongest predictor of the ability to run following TBI. The hierarchical organization of these mobility scales provides a guide to the stepwise selection of increasingly difficult tests of mobility. However, the hierarchy of mobility tasks does not indicate which physical factors are limiting high-level mobility outcomes. It is reasonable to assume that the ability to successfully perform the more difficult mobility tasks on the RMI and HiMAT, such as ascending and descending stairs, bounding and running require greater postural stability, push-off and coordinated movement. It may assist clinicians to know which physical factors are associated with better mobility performance in order to prioritize treatment planning and target specific therapeutic interventions.

Several case studies have been published describing the retraining of running in various neurological conditions. For example, Williams & Morris (2009) reported the feasibility of retraining running and high-level mobility in a cohort of people with a variety of neurological conditions including TBI and stroke. They reported clinically significant improvements in high-level mobility. However, none of these studies reported criteria used to determine when a person with a neurological condition was ready to run. In the absence of predictors for running, it may be pertinent to identify the factors which predict ability to run so that clinicians can make informed decisions regarding when to progress to this potentially risky activity. Therefore, the aims of this study were twofold: first, to identify which factors predict running performance; and second, to determine whether performance thresholds exist for those predictors.
Methods

This study formed part of a larger study which investigated mobility limitations following TBI. The methodology for this project has been previously reported in detail. Participants were required to undergo three-dimensional quantitative gait analysis (3DGA) in order to quantify postural stability, ankle power generation at push-off and quality of gait performance. Self-selected walking speed and the ability to run was also measured for each participant. This project was approved by Epworth Hospital’s HREC (study number 34006), and the University of Melbourne (Ethics ID: 060496.1).

Participants

One hundred and fourteen people with TBI were recruited for this project from Epworth Hospital, Melbourne, Australia. Patients currently attending physiotherapy for mobility limitations following TBI were asked to participate in this project. The inclusion criteria were: (a) had sustained a TBI and; (b) able to walk independently over a distance of 20 m without the use of a gait aid. Exclusion criteria were: (a) unwilling or unable to provide informed consent; (b) concurrent central nervous system disorders and; (c) or severe cognitive or behavioral problems that prevented assessment. All subjects who were invited to participate consented to do so.

Complete data were obtained for 97 of the 114 participants (Table 1). The 97 participants (72 male) with TBI were predominantly young and male, consistent with the broader TBI population. Of the 97 participants, 84 had a length of post-traumatic amnesia (PTA) greater
than 28 days, indicating extremely severe brain injury. Mean self-selected walking speed was equivalent to the speed required for community or outdoor mobility, but varied considerably between subjects. Length of time post-injury also varied considerably. On the whole, participants represented a severe and chronic cohort of people with TBI.

Three-dimensional gait analysis (3DGA)

3DGA was performed at the Centre for Health, Exercise and Sports Medicine, in the School of Physiotherapy at The University of Melbourne. Kinematic data were acquired using a motion analysis system (VICON 512, Oxford Metrics, Oxford, England) with eight cameras sampling at a rate of 120 Hz. Ground reaction force data were collected using three Kistler piezoelectric forceplates sampling at a rate of 1080 Hz. Twenty-five small (14 mm diameter) passive reflective markers were mounted on the skin at specific locations on the pelvis and both lower limbs following a previously described protocol. Subjects initially performed a standing calibration trial, with additional markers placed bilaterally on the medial femoral condyle, medial malleolus and proximal calcaneum of both legs. These markers were used to define joint centre locations and anatomical coordinate systems. The location of the hip joint centre was predicted using the method of Harrington et al. Data were recorded while participants with TBI performed walking trials over a 15 metre walkway at their self-selected speeds. Spatio-temporal, kinematic and kinetic data for five trials were collected for each lower limb to gain a representative sample of each participants gait pattern. Participants were given as much time to rest between trials as required in order to ensure fatigue did not influence performance.
The independent variables were measured as follows. Postural stability was quantified by lateral centre of mass (COM) displacement during a gait cycle, defined by the range between maximum and minimum values of a marker placed over the second sacral spinous process. Ankle power generation at push-off was defined as the peak value obtained in terminal stance for the more affected leg. Gait Profile Scores (GPS) were calculated to determine overall quality of gait performance. The GPS was chosen as it is the most accurate single index of gait performance, and has been previously reported in TBI. Nine kinematic measures of pelvic, hip, knee and ankle movements, together with foot progression, are collated and compared to the average values obtained from a sample of healthy controls (HC). The difference between the participant’s trace and the mean of the HC sample was calculated and summed into a representative GPS, with higher scores representing greater abnormality. Both legs were tested, and a single representative GPS was derived from the average of the scores obtained for each leg. In order to calculate GPS scores, a sample of 15 HCs were recruited for comparative purposes. In order to control for the effect of speed on kinematic and kinetic data, the HCs walked at a speed comparable to the mean (+/- 5%) TBI self-selected speeds. Self-selected walking speed was calculated from the toe marker during foot contact of consecutive steps (i.e. left/right stride length divided by time). Finally, in order to determine if the participants were able to run, a running trial was performed over a 20m distance. An assistant ran alongside the participant if required. Only participants who ran with a consistent flight phase (i.e. a flight phase between each foot contact) were categorised as being able to run. Thus, the primary dependent variable was dichotomous, (runner or non-runner). In addition to these measures, the high-level mobility of each participant was tested using the HiMAT. The HiMAT has a maximum score of 54, with higher scores indicating better performance.
Data Analysis

In order to calculate the independent variables, three-dimensional joint kinematic and kinetic calculations were performed using VICON Bodybuilder software (Oxford Metrics, Oxford, England) in accordance with a previously described approach. Summary statistics (mean, standard deviation and range) were calculated for each variable.

To determine the extent of the relationship between potential predictors and the ability to run, point-biserial correlation coefficients were calculated. A point-biserial correlation is used when continuous variables (gait speed, ankle power generation, lateral COM displacement and GPS) are correlated with a dichotomous outcome (able/unable to run). Logistic regression was performed to determine the impact of the predictor variables (postural stability, ankle power generation at push-off, quality of gait and self-selected walking speed) on the ability of participants to run.

For those factors which predict running, further analysis was conducted to determine whether performance thresholds exist. Performance thresholds for predictor variables were generated by maximizing Youden’s Index (YI = Sensitivity + Specificity – 1). Receiver Operating Characteristic (ROC) curves and sensitivity and specificity values were also calculated for each predictor variable. All statistical analyses were carried out with SAS® v. 9.2.

Results
The average HiMAT score was 20.5 (SD 12.0), ranging from 1 to 45. None of the participants were able to achieve a score within the 95% confidence intervals for normative HiMAT values, indicating significant high-level mobility limitations. The participants with TBI who were able to run, ran at a mean speed of 2.68 m/sec (SD = 0.51), well above the normal able-bodied walk to run transition speed. 

Individually, each predictor variable was strongly associated with the ability to run (Table 2). Higher self-selected walking speeds and better ability to generate ankle power for push-off were associated with greater likelihood of running. Less lateral COM displacement, indicating better dynamic postural stability, and lower GPS, indicating less walking abnormality, were also associated with a greater likelihood of running.

Logistic regression was performed to assess the impact of walking speed, dynamic stability, push-off and quality of gait on the ability of a person with TBI to run. The full model was statistically significant, \( \chi^2 (4) = 53.83, p < .001 \), yet only self-selected walking speed contributed significantly to the final model. The model correctly classified 80.9% of cases. As shown in Table 3, only self-selected walking speed contributed strongly to the final model, with an estimated odds ratio of 615.78. This estimate is quite imprecise, but the lower 95% confidence limit for this odds ratio (13.82) shows that the data are consistent with a very strong association.

Further analysis showed strong correlations between self-selected walking speed and lateral COM displacement (\( r = -.76, p < .001 \)), ankle power generation (\( r = .74, p < .001 \)), and GPS (\( r = -.35, p = .001 \)).
When partitioned into 0.1 m/s increments (Table 4), the odds-ratios for running demonstrate
that as self-selected walking speed increases by 0.1 m/sec, the odds of a person with TBI being
able to run approximately doubles. Figure 1 identifies runners and non-runners by self-selected
walking speed.

The area under the ROC curve (Figure 2) was large and statistically significantly different from
0.5 (0.90, 95% CI: 0.85 to 0.96, P < 0.001 (χ²=211.34, df=1), indicating that a self-selected
walking speed threshold of 1.06 m/sec provides a very reliable prediction method of running
ability, with a sensitivity of 0.86 and a specificity of 0.81. This means that the 1.0 m/sec
threshold correctly classified 86% of participants who had a self-selected walking speed ≥ 1.0
m/s as being able to run, and correctly classified 81% of participants walking at < 1.0 m/s as
not being able to run. Alternatively, rounding off self-selected walking speed and
dichotomizing to < 1.0 m/s or ≥ 1.0 m/s produced an odds ratio of 16.88 (95% CI: 6.38 to
44.67), indicating that if a person with TBI walks at a self-selected speed ≥ 1.0 m/sec, their
odds of being able to run are 16.9 times greater than for people who walk < 1.0 m/sec.

Discussion

Each of the proposed predictor variables were strongly associated with the ability to run.
Logistic regression analysis identified that self-selected walking speed was by far the most
important variable in predicting ability to run following TBI. Although many different factors
are important for normal walking, the results of this study suggest that self-selected walking
speed is an important factor for determining when a person with TBI is likely to be able to
progress to high-level mobility tasks. The strong result for self-selected walking speed may due to the correlations between it and the other predictors. Williams et al. (2010) also found strong relationships between self-selected walking speed and ankle power generation and lateral COM displacement.\textsuperscript{11} These findings indicate that higher self-selected walking speeds require greater ankle power generation and less lateral COM displacement (i.e. greater postural stability), and when analyzed together, ankle power generation and lateral COM displacement do not add significant unique variance. The clinical interpretation of this finding is that a person with TBI who walks at a self-selected speed $\geq 1.0$ m/sec (equivalent to $\leq 10.0$ sec for a 10m walk test or $\geq 360$m for a 6 minute walk test) is 16.88 times more likely to be able to run than a person who walks more slowly. Further, every 0.1m/sec increment in walking speed doubles the odds of running. In the absence of any clinical guidelines, and given the potential danger and risk of falling when attempting to run for the first time following TBI, we recommend that a self-selected walking speed of 1.0 m/s is required before it is reasonable to attempt to run.

The 1.0 m/s threshold walking speed for determining the ability to run is similar to the threshold speed for community mobility following stroke.\textsuperscript{17} Although self-selected walking speeds above 0.8 m/s are accepted as a standard for outdoor and community mobility following stroke, the ability to run is rarely investigated. In the few studies that have reported running outcomes following neurological injury, most do not report self-selected walking speed.\textsuperscript{22, 23, 25} Gardner et al. (1998)\textsuperscript{21} reported a self-selected walking speed of 1.22 m/s for a patient with spinal cord injury prior to commencing running training with body-weight support. Williams and Schache (2010)\textsuperscript{24} reported self-selected walking speeds of 0.90 m/s and 0.60 m/s for two patients with TBI who were unable to run. In all three cases, self-selected walking speeds
increased as the ability to run was attained. Self-selected walking speeds exceeding 1.0 m/s may still be significantly less than that of age and sex matched able-bodied counterparts, and do not guarantee a person with TBI can run, but should be used as an appropriate indicator to determine readiness for progressing to higher level mobility tasks.

The results of this study only provide a guide as to the speed at which someone needs to walk comfortably in order to increase their chance of running. It does not provide a definitive indication as to the cause of reduced self-selected walking speed for a person with TBI. Nor does this study indicate which aspects of physical performance or impairment need to be prioritized for treatment. Reduced postural control, reduced ankle power generation at push-off and gait abnormalities are common issues following TBI, and all may result in reduced self-selected walking speeds. It is acknowledged that there are many other factors that may influence a person’s ability to run. However, we included all the main physical variables which have been shown to influence mobility following TBI. Other factors which have been demonstrated to predict global outcome following TBI, such as Glasgow Coma Score, length of PTA and age, were not included in this study as they cannot be directly treated in rehabilitation. Nevertheless the results suggest that the higher self-selected walking speeds which are usually attained during the course of rehabilitation are associated with greater opportunity to perform advanced mobility tasks such as running.

The walk-to-run transition usually occurs spontaneously as walking speed increases. Increased walking speeds are primarily attained by increasing stride length, except for the initial 20% acceleration phase where stride frequency is the main factor. Spontaneous walk-to-run transition occurs at approximately 2.0 m/s, which may pose safety concerns for some
people with TBI. Although the 1.0 m/s threshold is only approximately three-quarters of the normal self-selected walking speed of young adult males, results indicate that it is not necessary for clinicians to wait for their patients with TBI to attain near-normal walking speeds before allowing progression to high-level tasks. Further, it is not necessary for clinicians to assess or train fast walking speeds (i.e. greater than able-bodied self-selected normative values), prior to considering running following TBI. Since many social, leisure, sporting and employment activities require high-level mobility skills, the 1.0 m/s self-selected walking speed threshold may be an important clinical indicator for the ability to run.

Clinical guidelines are usually developed from the combined knowledge obtained from a number of studies. This study is, to the best of our knowledge, the first to examine predictors for running following TBI, so the results should not be interpreted as a clinical guideline. However, clinicians do need to utilize the best available evidence in their clinical decision making. In the absence of any clinical guidelines for running for any neurological population, we recommend clinicians consider the 1.0 m/s threshold as an indicator for when a person with TBI may be able to run.

**Conclusion**

Postural stability, ankle power generation at push-off, quality of gait performance and self-selected walking speed were all strongly associated with the ability to run following brain injury. Nevertheless only self-selected walking speed contributed strongly to the final model. Self-selected walking speeds higher than 1.0 m/s greatly increase the likelihood of being able to run. The 1.0 m/s threshold, although slower than typical walking speeds for able-bodied
people, may be an important indicator for determining readiness to progress to high-level mobility tasks such as running during rehabilitation. Further investigations into predictors of running following TBI are required so clinical guidelines may be developed for the safe assessment of running and other high-level mobility limitations.

Reference List


### Table 1: Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Subjects With TBI (n = 97)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>72:25</td>
</tr>
<tr>
<td>Age (years)</td>
<td>30.2 (11.8)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.8 (8.7)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.5 (13.7)</td>
</tr>
<tr>
<td>Time post-injury (months)</td>
<td>54.6 (69.7)</td>
</tr>
<tr>
<td>Post-traumatic amnesia (days)</td>
<td>72.4 (53.4)</td>
</tr>
</tbody>
</table>
Table 2. Relationship between predictor variables and ability to run (n=97).

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Mean (SD)</th>
<th>Range</th>
<th>$r_{pb}$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral COM Displacement</td>
<td>93.2 (40.9)</td>
<td>38.9-246.2</td>
<td>-0.50</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Ankle Power Generation Push-off</td>
<td>1.25 (0.77)</td>
<td>0.01-3.40</td>
<td>0.48</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Gait Profile Score</td>
<td>11.3 (2.2)</td>
<td>7.4-21.2</td>
<td>-0.36</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Self-selected walking speed</td>
<td>0.99 (.37)</td>
<td>0.05-1.80</td>
<td>0.64</td>
<td>&lt; .01</td>
</tr>
</tbody>
</table>

P-values relate to the hypotheses that the true correlations are zero.
Table 3. Logistic Regression Modeling the Ability to Run (n=97)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>S.E.</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>P value</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-selected walking speed</td>
<td>6.42</td>
<td>1.94</td>
<td>10.99</td>
<td>1</td>
<td>.001</td>
<td>615.78</td>
<td>13.82</td>
</tr>
<tr>
<td>Lateral COM Displacement</td>
<td>-.01</td>
<td>.01</td>
<td>.14</td>
<td>1</td>
<td>.709</td>
<td>1.00</td>
<td>.97</td>
</tr>
<tr>
<td>Ankle Power Generation Push-off</td>
<td>-.21</td>
<td>.55</td>
<td>.15</td>
<td>1</td>
<td>.700</td>
<td>.81</td>
<td>.28</td>
</tr>
<tr>
<td>GPS</td>
<td>-.25</td>
<td>.17</td>
<td>2.11</td>
<td>1</td>
<td>.147</td>
<td>.78</td>
<td>.56</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.42</td>
<td>2.63</td>
<td>1.69</td>
<td>1</td>
<td>.193</td>
<td>.03</td>
<td></td>
</tr>
</tbody>
</table>

P-values relate to the hypotheses that the model coefficients are zero.
Table 4. Relationship between self-selected walking speed and the odds-ratio for running (n=114).

<table>
<thead>
<tr>
<th>Self Selected walking speed (m/sec)</th>
<th>10m walk time (sec)</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>0.1</td>
<td>100.0</td>
<td>1.901</td>
</tr>
<tr>
<td>0.2</td>
<td>50.0</td>
<td>3.614</td>
</tr>
<tr>
<td>0.3</td>
<td>33.3</td>
<td>6.870</td>
</tr>
<tr>
<td>0.4</td>
<td>25.0</td>
<td>13.061</td>
</tr>
<tr>
<td>0.5</td>
<td>20.0</td>
<td>24.830</td>
</tr>
<tr>
<td>0.6</td>
<td>16.7</td>
<td>47.204</td>
</tr>
<tr>
<td>0.7</td>
<td>14.3</td>
<td>89.737</td>
</tr>
<tr>
<td>0.8</td>
<td>12.5</td>
<td>170.596</td>
</tr>
<tr>
<td>0.9</td>
<td>11.1</td>
<td>324.314</td>
</tr>
<tr>
<td>1.0</td>
<td>10.0</td>
<td>616.540</td>
</tr>
<tr>
<td>≥1.1</td>
<td>≤ 9.1</td>
<td>&gt;999.999</td>
</tr>
</tbody>
</table>
Figure titles and captions

Figure 1. Distribution of Runners and Non-runners by Gait Speed and HiMAT Scores.

Figure 1 shows the relationship between self-selected walking speed, HiMAT scores and the ability to run. Runners are represented by the circles and non-runners by the dots. The vertical dashed reference line represents the 1.06 m/s threshold for running.

Figure 2: ROC Curve for Self-selected Walking Speed

The Receiver Operating Characteristic (ROC) curve demonstrates the sensitivity and specificity for classifying the ability to run at a 1.0 m/s self-selected walking speed threshold. A curve closer to the top left hand corner indicates a more sensitive and specific test.