How Much Do range of Movement and Coordination Affect Paralympic Sprint Performance?

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ABSTRACT

Introduction: Development of evidence-based methods of Paralympic classification requires research quantifying the relative strength of association between ratio-scaled measures of impairment and sports performance. To date, no such research has been conducted. The purpose of this study was to quantify the extent to which range of movement (ROM) and coordination affect running performance in runners with and without brain impairment. Methods: Participants were 41 male runners, 13 with brain impairments (RBI) and 28 non-disabled (NDR). All participants completed a maximal 60metre sprint as well as a novel battery of 5 lower limb ROM tests and 3 lower limb coordination tests. Results: In the coordination tests, RBI showed significantly slower mean movement times compared to NDR on all measures (e.g. 0.54s±0.12 vs. 0.34s±0.05). RBI had significantly lower range of movement on five of ten measures (e.g. 25.9° ±5.4 vs. 37.0° ±6.0) and had significantly slower acceleration (0-15m) (3.2s±0.3 vs. 2.8s±0.2) and top speed (30-60 m) (4.3s±0.6 vs. 3.8s±0.3). Five ROM measures significantly correlated with sprint performance in RBI and did not significantly correlate with sprint performance in NDR satisfying convergent and divergent validity criteria. These individual tests explained 38% to 58% of the variance in sprint performance in RBI. Conclusion: This is the first study to quantify the extent to which eligible impairments impact on performance in a Paralympic sport. Five of the ROM measures significantly affected sprint performance in RBI and were deemed valid for the purposes of classifying impairments in classes T35-T38. This study is an important methodological step towards development of evidence-based methods of classifying impairments in classes T35-T38 and provides practical methodological guidance to researchers in this field.

Keywords: Paralympics, disability sport, athletics, evidence-based classification, running
INTRODUCTION

Paralympic classification systems aim to promote participation in sport by people with disabilities by minimising the impact of eligible impairments on the outcome of athletic competition(13). Classification systems which achieve this aim will ensure that successful athletes will not simply be those with impairments that cause the least activity limitation, but will be those that have the most advantageous combination of physiological and/or psychological attributes and have enhanced them to best effect(13). In practice, athletes who are affected by impairments that cause a similar degree of activity limitation in a given sport should compete in the same class.

Paralympic classification systems comprise two key components: 1) Eligibility Criteria, which describe the types of impairments that are eligible, as well as how severe they must be; and 2) methods for assessing and classifying eligible impairments according to the extent of activity limitation they cause(12, 13). In Paralympic Athletics (i.e., Track and Field), people with brain impairments resulting in ataxia, hypertonia or athetosis (e.g., cerebral palsy or traumatic brain injury) are eligible for Paralympic running events, providing their impairments are deemed severe enough to impact on running performance(7). Runners affected by one or more of these impairment types compete in one of four classes: T35, for athletes whose running is moderately affected by spastic diplegia; T36 for running that is moderately affected by athetosis or ataxia; T37 for running moderately affected by spastic hemiplegia; and T38 for running mildly affected by hypertonia, ataxia or athetosis(7). Current methods for classifying these athletes include assessment of several factors, two of the most important of which are available range of movement (which is frequently impaired due to factors such as contracture or muscular co-contraction) and coordination (which is frequently impaired due to factors such as loss of
selective motor control or the persistent distal-segment motion and posturing characteristic of athetosis)(10). Unfortunately, the methods used for assessing and classifying impaired range of movement and impaired coordination are typical of many Paralympic classification systems in that methods lack standardization and there is little scientific evidence to indicate the strength of association which permit the results to inform class allocation(13).

In 2007 the IPC adopted the IPC Classification Code which, inter alia, explicitly mandated the development of evidence-based methods of classification in Paralympic sport(6). In order to develop evidence-based methods for classifying runners with brain impairments causing hypertonia, ataxia or athetosis, measures of range of movement and coordination which are precise, ratio-scaled and valid are required(12). These characteristics are necessary because they will permit the use of inferential statistics to quantify the relative strength of association between impairment and running performance. It is quantification of this relationship that is the fundamental basis of evidence-based classification(12). In addition to these measurement characteristics, valid tests of impairment should have two other characteristics: they should be impairment-specific (i.e. they should measure only one eligible impairment type, and not be confounded by the impact of other impairment types); and each measure should be sport-specific (i.e., they should assess those body segments which are most important to sports performance) to ensure each measure accounts for the greatest possible variance in sports performance(13). For example, tests of coordination for runners should focus on the lower limbs (because they are relatively more important for running performance than the trunk and arms) but testing should be conducted in a seated or semi-supported position so that the test outcome is not unduly influenced by leg strength, trunk strength and standing balance. Tests with these features will provide a measure of coordination which is specific to the sport of track running.
Unfortunately current methods for assessing impaired ROM and coordination for classification of runners do not meet these criteria. For example, impaired range of movement is assessed using goniometry where possible. However because of the general limitations of reliability(8, 9), the time-consuming nature of joint-by-joint measurement and the small amount of information yielded by a single measure, goniometry is usually reserved for key joints, with measures supplemented by more general, qualitative descriptors (e.g., athlete has a bilateral lower limb flexion pattern with moderately internally rotated hips and a bilateral extension deficit of 20° at both knees). The assessment of coordination is not standardized, but clinical tests such as finger-to-nose(11) are utilized and qualitative observations reported. While these methods of assessment have the advantage of requiring minimal equipment, their precision and reliability is not sufficient to permit development of evidence based methods of classification(12).

In order to permit the development of evidence-based methods for classifying runners with brain impairments causing hypertonia, ataxia or athetosis, a battery of tests with the required measurement features was developed for the purposes of assessing ROM and coordination. The aim of this study was to evaluate the validity of these tests for the purposes of classification. Two aspects of validity were assessed: convergent validity (i.e., does the test have a strong, significant relationship with sprint performance in runners with brain impairments) and divergent validity (i.e., does the test have a weak, non-significant relationship with sprint performance in non-disable runners)(4).
METHODS

Participants were 41 males who competed regularly in running events or in a sport in which running speed is a performance determinant (e.g. football). Thirteen were runners with brain impairments (RBI) and 28 were non-disabled runners (NDR). All RBIs had an official IPC classification, a process which includes medical confirmation of a brain impairment causing hypertonia, ataxia or athetosis and resulting in activity limitation in running. Distribution of athletes per class was: T35 (n=2); T36 (n=1); T37 (n=6); and T38 (n=4). The mean (± S.D.) age (yrs), height (m) and body mass (kg) for RBI was 24.3 (±9.4), 1.76 (±0.09), 69.1 (±9.6) respectively. Mean age, height and body mass for NDR was 23.1 (±4.1), 1.81 (±0.07), 76.7 (±9.5). All participants provided written informed consent, and the study was approved by the Medical Research Ethics Committee at the University of Queensland, Australia.

Procedures

All participants completed one 2 hour testing session in which they completed three categories of tests in a randomized order: 1) five tests of ROM; 2) three tests of coordination; and 3) a 60m maximal sprint. The order of testing for the five tests of ROM and three tests of coordination was also randomised. Each test was completed three times with the best performance used for analysis. A minimum of 3 minutes recovery was required between each maximal sprint (a combination of walking back to the start line and passive recovery). Subsequent sprint trials were conducted when the participant indicated they were ready. Coordination and ROM tests were not physically demanding and trials were separated by recoveries of at least 30 seconds. Participants wore their own footwear but orthotics and other aids/assistive devices were not permitted.
Tests of ROM

Lower limb ROM was assessed using a 5-test battery (Figures 1 and 2). A calibrated Acumar digital inclinometer (Lafayette Instrument, IN, USA) was used to measure segment angles, and segment lengths were measured using a segmometer (Rosscraft Innovations, CA). A limitation of digital inclinometers is the measurement instability from placing the inclinometer on the musculature. To overcome this problem, a rigid acrylic base (0.085m x 0.065m) was strapped to the segment at an anatomically standardized location prior to movement. The acrylic base provided a flat, level surface from which to obtain inclinometer measures. All tests were administered by two researchers who had 2 years experience conducting the tests. Tests were completed on each leg individually yielding 10 outcome measures. Unpublished data from our laboratory suggests that these tests are reliable (inter-tester mean ICC = 0.89).

Maximum Thigh Flexion and Heel Pull Distance

Participants started in a supine position with the legs fully extended and the feet resting against a wall before maximally flexing the testing leg at the knee and hip. At maximal leg flexion, two separate outcome measures were obtained – maximum thigh flexion and heel pull distance, which was defined as the distance on the non-tested leg between the wall and the position that the heel of tested leg finally reached (Figure 1A).
Maximum Thigh Extension

Participants stood on a platform (0.1m x 0.3m x 0.22m) leaning with the back against a concrete pylon so that the testing leg could swing freely but the non-tested side was fully supported. The heel of the non-tested leg was 0.15m away from pylon. Participants placed their hands on chairs to increase stability. Whilst maintaining full extension on the stance leg, participants maximally extended the leg prior to measurement of thigh angle (Figure 1B).

Dorsiflexion Lunge

While maintaining heel contact with the ground, participants reached maximal dorsiflexion on the tested leg by lowering the centre of mass and flexing the knee. The participants were permitted to move the non-testing leg into a self-selected comfortable position, and placed their hands on chairs to maintain stability. Tibia angle was measured at maximal dorsiflexion (Figure 2A).

Backward Stepping Lunge

The shank of one leg was maintained at 90° whilst the contralateral leg was moved backwards as far as possible. Chairs positioned either side of the participant were used to maintain stability. Once maximal range was achieved, the distance between the most anterior phalanx of the back foot and the heel of the front foot was measured (Figure 2B).
Tests of Coordination

Coordination was assessed using three lower limb reciprocal tapping tasks: Reciprocal Unilateral Tapping with 0.05m target (RUT5); Reciprocal Unilateral Tapping with 0.12m target (RUT12); and Reciprocal Bilateral Tapping (RBT). An example of the coordination setup is shown for RBT in Figure 3. Unpublished data from our laboratory indicates the reliability of these tests is acceptable (mean ICC = 0.87).

For RUT5, participants perched on a table at the height of the greater trochanter, so that body weight was principally born through the buttocks, with support and stability from the non-testing foot. Two custom-made, 0.175m x 0.120m fibreglass printed circuit boards (PCBs) were positioned in the frontal plane 0.128m apart, on a platform which was 0.38m in front of the bench and which was designed to allow the PCBs to be positioned at 20° to the horizontal. The short side of the PCB faced the participant and the middle 0.05m of each PCB was marked as a target area. The PCBs were designed to register contact and comprised 60 gold-plated, longitudinal copper tracks which were 0.002m apart. Each PCB was connected to a personal computer via a Musclelab unit (Ergotest, Norway). Conductive copper tape was attached to the plantar surface of the big toe of the testing foot of the participant and when the toe made contact with the PCBs and two or more consecutive tracks were bridged, a 5V pulse was registered as a contact. The Musclelab software calculated the movement time between one contact and the next to the nearest one-hundredth of a second. Participants could begin the tests in their own time and were instructed to reciprocally tap the plates within the 0.05m target area as rapidly and accurately as possible for 15 seconds using the big toe. Accuracy was considered to be compromised when successful hits were <90%, in which case the trial was repeated. Prior to
starting, participants completed 3 practice trials at slow, medium and maximal speeds. The mean time taken to move the toe between the targets was calculated for each trial.

Participant set up and instructions for RUT12 was exactly the same as for RUT5 except that the PCBs were positioned directly next to each other and participants could touch anywhere in the 0.12m-wide PCB.

For RBT, participants sat on the bench with no support from the legs. Four PCBs were positioned in a 2x2 formation on the platform in front of the participant. The PCBs closest to the participant were positioned side-by-side and tilted at 15° angle towards the front PCBs. The front PCBs were tilted to 30° angle towards the back PCBs. Participants started by simultaneously tapping the right front PCB with the right toe and the left back PCB with the left toe and then, as quickly as possible, swapping their foot positioned so that they could simultaneously tap the right back PCB with the right toe and the left front PCB with the left toe. This constituted one cycle and participants were asked to perform as many cycles in 15 seconds as possible. Mean movement time was the outcome measure for RBT.

**Test of Performance - 60m Maximal Sprint**

All participants completed a 60m maximal sprint on a synthetic athletics track. A Cheetah LMT (AMR Sports, Australia) measured linear displacement of the participants(14). The Cheetah LMT unit consists of 100metres of Berkley fireline fishing line wrapped around a spool (0.1m circumference) which had a hole positioned every 0.01m. The circumference of the spool passed in front of a photo-electric device. The unit was secured to a table surface at approximately waist height and the line was attached to around the waist of the participants. As the participant
accelerated, the fishing line was pulled from the spool, causing it to spin in front of the photo-electric device. Each hole in the spool circumference permitted light to reach the device, sending a pulse to a connected onboard microprocessor. The onboard microprocessor measures the time taken between each pulse (every 0.01m increment). The Cheetah LMT analog signal was stored digitally as time (to the nearest one-hundredth of a second) per centimeter and from these data the time to 15m (acceleration phase) and time between 30m to 60m (maximal velocity phase) were calculated.

Statistical Analyses

The results for the right and left leg data in each unilateral test were organised according to the best performing side (best leg) and the worst performing side (worst leg) for every participant (both NDR and RBI). Independent t-tests with Benjamini-Hochberg(1) corrections for multiple comparisons were used to determine whether there was a significant difference between RBI and NDR on measures of ROM, coordination and sprint performance. Validity was tested using Pearson correlation coefficients to evaluate the relationship between outcome measures and sprint performance. A test was considered valid when the outcome measure was significantly related to sprint performance in RBI (convergent validity) and was not significantly related to sprint performance in NDR (divergent validity).
RESULTS

Mean times (± SD) for NDR were 2.8s (±0.2) for 0m-15m and 3.8s (±0.3) for 30m-60m. For RBI, times were 3.2s (±0.3) for 0m-15m and 4.3s (±0.6) for 30m-60m, both of which were significantly slower than NDR (p<0.05).

One of the RBI sample was unable to complete the ROM test battery. Consequently analyses of outcomes from measures of ROM - means, standard deviations, and Pearson correlation coefficients – are presented in Table 1 for 12 participants. Compared with NDR, range of movement was reduced in RBI on all 10 measures but the reduction was only significant for four measures: Heel Pull Distance and Dorsiflexion Lunge on the best and worst legs.

Five measures satisfied criteria for convergent validity (i.e., were significantly correlated with time from 0-15m, 30-60m or both in RBI) and divergent validity (i.e., were not significantly correlated with sprint performance outcomes in NDR): Heel Pull Distance on the best and worst legs, Maximum Thigh Flexion best leg, Maximum Thigh Extension best leg and Dorsiflexion Lunge best leg. The proportion of the variance in sprint performance in RBI accounted for by these five measures is presented in Table 1 and Figure 4 presents results for Dorsiflexion Lunge which illustrates the pattern of results required to satisfy criteria for convergent and divergent validity. Specifically, the correlation with both elements of sprint performance in RBI is significant and Dorsiflexion Lunge results explained 46% of the variance in 0-15m performance (Panel A) and 53% of the variance for 30-60m (Panel B). However, the same test explained only 2% of the variance for time from 0-15m in NDR, and less than 1% of the variance for 30-60m in the same group, illustrating divergent validity.
Table 2 presents the results from measures of coordination. Mean movement times were significantly slower for RBI compared to NDR for all measures of coordination \((p<0.01)\). None of the coordination measures significantly correlated with sprint performance for either RBI or NDR.

**DISCUSSION**

This study is a critical methodological advance in the development of evidence-based methods of Paralympic classification, being the first study to empirically quantify the extent to which eligible impairments adversely affect performance in a Paralympic sport. Such knowledge is an essential requirement for the development of evidence-based Paralympic classification systems\(^{(13)}\) and this study provides methodological guidance on how the requisite knowledge can be acquired. Importantly, the ROM and coordination tests evaluated in this study were ratio-scaled and precise and it was these features that permitted the use of inferential statistics to quantify their impact on running. Methods of assessment currently used in classification would not permit such analyses\(^{(12)}\).

Participants completed eight tests on both legs and four of these tests yielded five measures which satisfied convergent and divergent validity criteria: Heel Pull Distance (best leg); Heel Pull Distance (worst leg); Dorsiflexion Lunge (best leg); Maximum Thigh Extension (best leg); and Maximum Thigh Flexion (best leg). While these tests alone will not permit comprehensive or definitive classification of athletes currently eligible to compete in classes T35-T38, they can be directly applied, together with knowledge of their relative importance in running performance, to improve the evidence underpinning current classification methods in the sport. Results may
also be applicable in other Paralympic sports in which athletes with brain impairments run, including seven-a-side football and Para-triathlon.

It is noteworthy that of the five valid measures, four were obtained from the best leg. A similar pattern of results has been reported in a study of cyclists with cerebral palsy, which found that isokinetic muscle strength in the best leg was more strongly correlated with peak aerobic capacity than strength in the worst leg(3). This pattern may be partly explained by the fact that athletes whose best leg is relatively unimpaired are also likely to have a relatively unimpaired worst leg. However, this cannot be the whole explanation because otherwise there would also be a significant association between worst leg and performance. Therefore the results may indicate that athletes with a relatively unimpaired best leg can compensate more effectively for the activity limitation caused by the more affected leg.

While the current study was the first to quantify the effect of an eligible impairment on a Paralympic sport, one other study investigated the strength of association between a standardised upper limb activity assessment and four measures of impairment - ROM, coordination, strength and spasticity(2). Results indicated that 25% of the variance in the upper limb assessment was explained by a combination of ROM, coordination, spasticity and strength(2), indicating that there may have been an interaction between the measures of impairment. Two results from the current study were consistent with this finding. Firstly, four of the five valid ROM measures required active movement, reflecting not only passive joint range but also factors such as voluntary strength and hypertonia. Secondly, although there was no significant difference between NDR and RBI on two of the measures of ROM - Maximum Thigh Flexion and Maximum Thigh Extension – both of these measures were predictive of performance in RBI but not NDR. This indicates that the predictive validity of these tests may be mediated by other
statistically significant differences between the groups, including measures of coordination (N = 5) and ROM (N = 5). The relatively small sample size in the current study precluded multiple regression analyses to evaluate the relative contribution of different coordination and ROM impairments on activity limitation in sprinting. Our results indicate that future studies which are sufficiently powered for such analyses are now warranted.

Results indicate that, although lower limb coordination in RBI was significantly reduced compared with NDR, there was no significant association between these measures and sprint performance in RBI. This result was unexpected, and may be multifactorial. Firstly, our sample had relatively mild impairments compared with the general population of people with brain impairments. This is attributable at least in part to the fact that classes T35, T36 and T37 are not hierarchical (i.e., progressing from people with impairments causing the most activity limitation to people causing the least). Instead, all three are for athletes with impairments causing moderate activity limitation, with differentiation based on type/distribution of impairment - T35 for diplegia, T36 for ataxia or athetosis and T37 for hemiplegia(7). As a consequence, among athletes who are eligible for these classes, there is a systematic bias in favour of those with impairments causing the least activity limitation (i.e., those closest to being class T38). This discourages participation among those with more severe impairments, making it difficult to recruit such athletes. Secondly, only one athlete in the RBI sample was affected by either ataxia or athetosis, and it is incoordination resulting from these impairment types that our measures of coordination were most likely to be sensitive to. A sample of RBI with a higher number of athletes with ataxia or athetosis may yield a significant relationship and, given the relatively lower incidence of ataxia and athetosis (5), recruiting higher numbers of athletes with these impairments may require multicenter studies utilizing international collaborations. Finally, the
relatively low correlation between our tests of coordination and sprint performance may be explained by the fact that these tests of coordination were designed to be impairment-specific (i.e. unconfounded by impairments of strength or balance) and were therefore performed in a seated position. While impairment-specificity is a crucial feature of impairment tests, it is possible that a greater degree of sport specificity is required in these tests. Future research might investigate the validity of more sport specific tests of coordination (e.g., rapid cyclical movements in weight-bearing position, like running-on-the-spot).

In conclusion, this is the first study to empirically quantify the extent to which eligible impairments impact on performance in a Paralympic sport. In doing so, it provides methodological guidance to researchers in this field. Five of the ROM measures evaluated can be directly applied to improve the evidence underpinning classification of eligible types of impairment in classes T35-T38, these being: Heel Pull Distance (best leg); Heel Pull Distance (worst leg); Dorsiflexion Lunge (best leg); Maximum Thigh Extension (best leg); and Maximum Thigh Flexion (best leg). In addition to providing a model for future studies advancing the evidence-based classification research agenda in other Paralympic sports, results from this study indicate the need for a range of other studies, including: studies investigating the extent to which impaired strength affects sprint performance in athletes who are eligible for classes T35-T38; studies with samples comprising a greater proportion of athletes with ataxia and athetosis and/or more severe impairments; and studies which are sufficiently powered to explore the unique and shared variance explained by measures of strength, coordination and range of movement in RBI.
Competing Interests: The authors have no competing interests. The results of the present study do not constitute endorsement by ACSM.

Acknowledgments: This research was supported by the Australian Research Council (grant LP0882187), the International Paralympic Committee, the Australian Sports Commission and the Australian Paralympic Committee.
REFERENCES


FIGURE CAPTION

Figure 1. Panel A shows Maximum Thigh Flexion and Heel Pull Distance. Maximum Thigh Flexion was defined as the angle between the tested thigh and the horizontal. The outcome measure for Heel Pull Distance was the distance on the non-tested leg between the wall and the position that the heel of tested leg finally reached. Panel B shows Maximum Thigh Extension which was defined as the angle between the tested thigh and the vertical. Segment angles were measured using a digital inclinometer (Lafayette Instrument, IN, USA).

Figure 2. Panel A shows Dorsiflexion Lunge. The outcome measure for Dorsiflexion Lunge was tibia angle which was defined as the angle between the tested tibia and the horizontal. Panel B shows Backward Stepping Lunge. The outcome measure for the Backward Stepping Lunge was the distance between the most anterior phalanx of the back foot and the heel of the front foot.

Figure 3. The setup for the RBT coordination test. Participants sat on the bench with no support from the legs. The back PCBs (closest to the participant) were tilted at 15° angle towards the front PCBs. The front PCBs were tilted to 30° angle towards the back PCBs. Participants simultaneously tapped the right front PCB with the right toe and the left back PCB with the left toe and then, as quickly as possible, swapped their feet position so that they simultaneously tapped the right back PCB with the right toe and the left front PCB with the left toe. Participants were asked to perform as many of these cycles in 15 seconds as possible. Mean movement time was the outcome measure for all of the coordination tests.
Figure 4. Panels A and B present dorsiflexion lunge vs acceleration (0-15m) and dorsiflexion lunge vs maximal velocity (30-60m) respectively. In each panel, the coefficient of determination (R2) is presented in the top right of the panel for Runners with Brain Impairments (RBI) and for Non-disabled Runners (NDR). In each case, R2 is significant for RBI but not for NDR (p<0.05).
Figure 1

A

Distance Measured

B

ACCEPTED
Figure 2
Figure 3
Figure 4
Table 1: Analysis of results (n=12) from ROM tests including mean ranges and standard deviations for each test, and the correlations (r) and coefficient of determinations ($R^2$) with time for 0-15m and time for 30m-60m.

<table>
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<th>Test</th>
<th>Limb</th>
<th>Group</th>
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<th>30m to 60m</th>
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<td></td>
<td></td>
<td>r</td>
<td>$R^2$</td>
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<td>Maximum Thigh Flexion (°)</td>
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<td>Heel Pull Distance (m)</td>
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<td>0.58 (0.07)**</td>
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<td>RBI</td>
<td>1.88 (0.28)</td>
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<td>.12</td>
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NDR = non-disabled runners; RBI = runners with brain impairments; Best = least impaired leg; Worst = most impaired leg; * (p<0.05) and ** (p<0.01) indicates RBI is significantly different from NDR; † (p<0.05) and †† (p< 0.01) indicates significant correlation
Table 2: Analysis of results (n=13) from coordination tests including mean movement times and standard deviations for each test, and correlations (r) and coefficient of determination ($R^2$) with time for 0-15m and time for 30m-60m.

<table>
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<td>.18</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RBI</td>
<td>.54 (.12)**</td>
<td>.12</td>
<td>.01</td>
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<tr>
<td>RUT12 (s)</td>
<td>Best</td>
<td>NDR</td>
<td>.25 (.03)</td>
<td>.02</td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RBI</td>
<td>.35 (.07)**</td>
<td>.22</td>
<td>.05</td>
</tr>
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<td>Worst</td>
<td>NDR</td>
<td>.29 (.03)</td>
<td>-.04</td>
<td>.00</td>
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<tr>
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<td>RBI</td>
<td>.40 (.08)**</td>
<td>.16</td>
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<tr>
<td>BRT (s)</td>
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<td>.30 (.05)</td>
<td>.00</td>
<td>.00</td>
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<td></td>
<td>RBI</td>
<td>.63 (.26)**</td>
<td>.21</td>
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</tr>
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</table>

NDR = non-disabled runners; RBI = runners with brain impairments; RUT5 = Rapid Unilateral Tapping with a 5cm target; RUT12 = Rapid Unilateral Tapping with a 12cm target; BRT = Bilateral Rapid Tapping; Best = least impaired leg; Worst = most impaired leg; ** (p<0.01) indicates RBI is significantly different from NDR.