**TECHNICAL NOTE**

Technical Report: Gait Performance at Two Speeds and Carrying Capacity by Men with an Osteomyoplastic Transfemoral Limb and Comparable Controls

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**ABSTRACT**

**Introduction:** With advances in surgical approach like osteomyoplastic amputation, it is unknown whether outcomes of walking at different speeds or carrying performance by men with an osteomyoplastic transfemoral limb (OTFL) are comparable with those of intact controls.

**Materials and Methods:** Otherwise healthy men with unilateral OTFL and intact controls consented to participate. All were independent walkers without history of diabetes or other dysvascular condition. All underwent 2-minute walk tests (2MWTs) at self-paced and brisk-paced speeds and 25-ft carry-to-capacity testing as part of a multiyear work performance study. For the current report, investigators compared walking and carrying baseline outcomes between OTFL and control groups.

**Results:** Six men with OTFL (mean age, 33.7 ± 14.8 years) and 20 controls (mean age, 31.7 ± 11.1 years) completed the study. No initial differences between groups were found in age, height, weight, heart rate, blood oxygen saturation, hemoglobin A1c, overall reported pain, or report of perceived exertion scores. However, the OTFL group walked shorter mean distances at self-paced (137.2 ± 18.1 m) and brisk-paced (167.8 ± 20.3 m) 2MWTs than the controls did (self-paced, 155.7 ± 19.9 m, P = 0.015; brisk paced, 211.7 ± 3.0 m, P < 0.0001) and demonstrated less 25 ft-carry capacity (18.1 ± 9.7 kg) than the controls did (26.8 ± 3.1 kg; P = 0.001). Reported pain by the OTFL group was greater only during carry testing (P < 0.046).

**Conclusions:** Despite receiving similar, well-fitted prosthetic limbs and standard rehabilitation after osteomyoplastic amputation, the OTFL group demonstrated lower walking and carrying capacities than a comparable control group. Results may reflect that the OTFL group may still be at risk of injury, demonstrating the need for further investigation of gait and other work performance outcomes by work-eligible men with OTFL and standard rehabilitation approaches. (*J Prosthet Orthot.* 2021;00:00–00)

**KEY INDEXING TERMS:** osteomyoplastic transfemoral limb loss, work performance

Approximately 185,000 lower-limb amputation surgeries are performed in the United States each year, and 27% of them are performed proximal to the knee joint, that is, knee disarticulation or transfemoral amputation. Fifty percent of those with transfemoral amputation are of the working age (21–65 years), whose percentage will increase by 27% over the next 10 years because of survival from combat or pathologic conditions that lead to amputation. However, despite advances in technology, medicine, prosthetics, and rehabilitation, the US Department of Labor estimates that 64.1% of those with lower-limb amputation who are employable and could return to a productive life after amputation are not part of the workforce.

For those in the working-age group with transfemoral limb loss (TFL), it is imperative that surgery, prosthetics, and rehabilitation strategically focus on returning these individuals to the workforce and remain otherwise healthy and work-eligible. However, the working-age adults with TFL still struggle with job reentry and retention. According to the US Department of Labor, the unemployment rate for working-age adults with any limb loss in March 2009 was 13.1%, compared with considerably lower rates for those without limb loss. And, many with amputation fail to enter or reenter the workforce. In short, many otherwise employable people with TFL are not actively at work.

The osteomyoplastic technique, still considered a novel surgical approach to transfemoral amputation, was originally described by Janos Ertl, MD, in the early 1900s. The premise of the technique was to use osteoperiosteal flaps to close the medullary canal, reestablish soft tissue balancing, create a cylindrical limb that can accept a prosthesis, prevent severe abduction of the residual limb, and provide adequate distal soft tissue coverage. The surgical approach to osteomyoplastic transtibial amputation as well as the respective rehabilitation has been
documented in the literature. However, there is a paucity regarding work performance outcomes related to osteomyoplastic transfemoral limb (OTFL) with current, standard rehabilitation approaches.

The walking performance of adults with transfemoral amputation in general has been previously examined.9–13 For example, Boonstra and colleagues13 compared self-paced and brisk walking performed by 24 men and women with transfemoral limb loss (transfemoral and knee disarticulation) and 15 healthy intact controls. The investigators determined that the mean self-selected gait speed and brisk-paced gait speeds were significantly slower in the groups of individuals with amputations than controls.13 However, comparability between working-age men, specifically with OTFL, and controls performed at different speeds or burden (carry capacity) has yet to be examined. The following report is from the initial segment of a completed multiyear work performance study.14 The purpose of the current study was to compare performance outcomes from the 2-minute walk test (2MWT) at self- and brisk-paced walking speeds15 and 25-ft carrying test between otherwise healthy men with unilateral OTFL and intact controls.

METHODS

Investigators applied the following selection criteria: English speaking; “working-age” men (18–64 years); without significant medical (endocrine [e.g., diabetes], cardiorespiratory, peripheral vascular, neuromuscular, inflammatory) conditions that prevent the self-paced walking, brisk walking, or carrying tasks that this study evaluated; absence of open wound on lower limbs; and independence in gait without use of equipment. Because of the commonality of undiagnosed and uncontrolled diabetes in the population being sampled,2 all participants were tested for diabetes (hemoglobin A1c [HbA1c]) and gross distal lower-limb sensation deficits (monofilament testing)16 to ensure that all possessed protective sensation (5.07/10-g monofilament)16 as well as have normal-to-well controlled blood glucose levels (5% < HbA1c < 7%).17 Men specifically were studied because most working-age adults with TFL are men,18 with less variation in overall bone density or biomarkers for inflammation in this age group.18 In the current study, men with OTFL underwent either ostomyoplastic transfemoral or knee disarticulation amputation by the surgeon investigator.

RESULTS

PARTICIPANTS

Six men with OTFL and 20 controls completed the study (Table 1). In the OTFL group, all received standard rehabilitation; prosthetic componentry and fit were determined to be adequate by the prosthetist investigator.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age, y</th>
<th>Height, m</th>
<th>Weight, kg</th>
<th>Mean Calculated BMI</th>
<th>HR, bpm</th>
<th>Sat O2 (%SpO2)</th>
<th>VAS Pain (0–10 cm)</th>
<th>HbA1c, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limb loss</td>
<td>6</td>
<td>33.7 ± 14.8</td>
<td>1.8 ± 0.1</td>
<td>83.8 ± 16.4</td>
<td>25.6 ± 37.2</td>
<td>81.5 ± 11.8</td>
<td>97.3 ± 1.4</td>
<td>0.5 ± 1.2</td>
<td>5.17 ± 0.5</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>31.7 ± 11.1</td>
<td>1.8 ± 1.8</td>
<td>85.5 ± 83.3</td>
<td>24.2 ± 25.7</td>
<td>72.5 ± 11.0</td>
<td>97.6 ± 1.4</td>
<td>0.2 ± 0.7</td>
<td>5.23 ± 0.4</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>P = 0.871</td>
<td>P = 0.442</td>
<td>P = 0.778</td>
<td>P = 0.691</td>
<td>P = 0.085</td>
<td>P = 0.530</td>
<td>P = 0.415</td>
<td>P = 0.988</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD.
BMI indicates body mass index; HR, heart rate; VAS, visual analog scale; HbA1c, hemoglobin A1c.
WALK TESTS

The OTFL group walked shorter mean distances in the self-paced 2MWT (137.2 ± 18.1 m) than the controls did (155.7 ± 19.9 m; \( P = 0.015 \)) and in the brisk-paced 2MWT (OTFL, 167.8 ± 20.3 m) than the controls did (211.7 ± 23.1 m; \( P < 0.0001 \)) (Table 2).

CARRY TEST

Men with OTFL also demonstrated less capacity in carrying a weighted test box a distance of 25 ft (18.1 ± 4.4 kg) than the controls did (26.7 ± 4.6 kg; \( P = 0.001 \)). It should be noted that the limb-loss group also reported higher visual pain scale scores only during the carrying task (1.83/10 ± 1.83 cm) than the controls did (0.10/10 ± 0.45 cm; \( P = 0.046 \)) (Table 2).

COMPARABILITY BETWEEN GROUPS

No differences were found between the OTFL group and the control group in age, height, weight, heart rate, blood oxygen saturation, HbA1c, overall initial pain scores, or report of perceived exertion scores (\( P > 0.05 \)). For this report, we also calculated the mean body mass index (BMI) per group based directly on participant height and weight. Overall, the groups' similar calculated BMI were between the “normal” and “overweight” categories, with the OTFL group insignificantly heavier than the control group as seen in Table 1. All OTFL participants were weighed while wearing their prosthetic limb. All of the OTFL participants used similarly constructed lower-limb prostheses deemed appropriate by the prosthetist investigator. Each OTFL participant reported having undergone standard rehabilitation after osteomyoplastic transfemoral or knee-disarticulation amputation surgery conducted by the surgeon investigator. All of the participants with OTFL reported well-controlled perceived exertion during the trials and little to no pain during the walk testing. These two groups should be considered appropriate to compare walk and carry performance.

GAIT SPEED COMPARISON WITH ANOTHER PUBLISHED STUDY

The 2MWT data from the current study were compared with data from a previously published investigation of transfemoral

Table 2. 2-Minute walk test (2MWT) and 25-foot carrying test—limb loss and control groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Distance or Amount</th>
<th>Post HR, bpm</th>
<th>Sat O₂ (%SpO₂)</th>
<th>RPE (6–20)</th>
<th>VAS pain (0–10 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Self-paced 2MWT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limb loss</td>
<td>6</td>
<td>137.2 ± 18.1 m</td>
<td>145.2 ± 141.3</td>
<td>97.3 ± 1.2</td>
<td>8.5 (6–11)</td>
<td>0.5 ± 1.2</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>155.7 ± 19.9 m</td>
<td>79.8 ± 16.5</td>
<td>94.6 ± 3.9</td>
<td>6 (6–8)</td>
<td>0.1 ± 0.5</td>
</tr>
<tr>
<td>Total/sig</td>
<td>26</td>
<td>( P = 0.045 )</td>
<td>( P = 0.120 )</td>
<td>( P = 0.092 )</td>
<td>( P = 0.083 )</td>
<td>( P = 0.231 )</td>
</tr>
<tr>
<td><strong>Brisk-paced 2MWT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limb loss</td>
<td>6</td>
<td>167.8 ± 20.3 m</td>
<td>102.8 ± 20.3</td>
<td>97.3 ± 1.8</td>
<td>10.5 (8–13)</td>
<td>1.3 ± 2.2</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>211.7 ± 23.1 m</td>
<td>99.5 ± 21.4</td>
<td>96.1 ± 0.7</td>
<td>9 (8–13)</td>
<td>0.3 ± 0.64</td>
</tr>
<tr>
<td>Total/sig</td>
<td>26</td>
<td>( P &lt; 0.0001 )</td>
<td>( P = 0.82 )</td>
<td>( P = 0.125 )</td>
<td>( P = 0.118 )</td>
<td>( P = 0.324 )</td>
</tr>
<tr>
<td><strong>25-ft carry</strong></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Limb loss</td>
<td>6</td>
<td>18.1 ± 4.4 kg</td>
<td>94.7 ± 15.0</td>
<td>96.8 ± 1.2</td>
<td>9 (8–13)</td>
<td>1.2 ± 1.8</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>26.7 ± 4.6 kg</td>
<td>94.9 ± 16.8</td>
<td>96.5 ± 2.8</td>
<td>11 (8–17)</td>
<td>0.1 ± 0.5</td>
</tr>
<tr>
<td>Total/sig</td>
<td>26</td>
<td>( P = 0.001 )</td>
<td>( P = 1.0 )</td>
<td>( P = 0.49 )</td>
<td>( P = 0.178 )</td>
<td>( P = 0.046 )</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD or median (range). Data in bold indicate significant \( P \) levels (\( P < 0.05 \)). HR indicates heart rate; RPE, rating of perceived exertion; VAS, visual analog scale.

Table 3. Gait speed without equipment by limb loss and control groups from the current study and Boonstra et al.13

<table>
<thead>
<tr>
<th>Group</th>
<th>Study Gait Speed</th>
<th>Boonstra et al.13</th>
<th>Study Gait Speed</th>
<th>Boonstra et al.13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self-paced 2MWT</td>
<td>Self-paced</td>
<td>Brisk-Paced</td>
<td>Brisk-Paced</td>
</tr>
<tr>
<td>Limb loss</td>
<td>n = 6 (combined)</td>
<td>n = 16 (Transfemoral)</td>
<td>n = 6 (combined)</td>
<td>n = 16 (Transfemoral)</td>
</tr>
<tr>
<td></td>
<td>1.1 ± 0.2 m/s</td>
<td>• 1.0 ± 0.2 m/s</td>
<td>1.4 ± 0.2 m/s</td>
<td>• 1.3 ± 0.3 m/s</td>
</tr>
<tr>
<td>Control</td>
<td>n = 20</td>
<td>n = 15 (Knee disarticulation)</td>
<td>n = 20</td>
<td>n = 15 (Knee disarticulation)</td>
</tr>
<tr>
<td></td>
<td>1.30 ± 0.17 m/s</td>
<td>• 1.2 ± 0.3 m/s</td>
<td>1.75 ± 0.19 m/s</td>
<td>• 1.5 ± 0.36 m/s</td>
</tr>
</tbody>
</table>

2MWT indicates 2-minute walk test.
gait speed by Boonstra et al. that used a 10-m walk test to compare gait speed between adults with TFL and intact controls. As seen in Table 3, the OTFL group in the current study and the limb-loss participants in the Boonstra et al. study demonstrated slower gait speed than the respective control groups. The OTFL group in the current study walked at speeds within the range of self-paced and brisk-paced gait speeds set by the transfemoral and knee disarticulation participant groups in the Boonstra et al. study.

However, threats to comparability were that the current study had fewer participants, included only men, and did not divide the participants’ data into either a transfemoral or knee disarticulation subgroup. Furthermore, it is unknown whether the participants in the Boonstra et al. study underwent conventional or osteomyoplastic amputation surgical procedures. In addition, in the current study, controls’ gait speeds were slower in general than those of the controls in Boonstra et al. during the self-paced and brisk walking tests. However, both the current study and the Boonstra et al. study tested adults with transfemoral limb loss at self-paced and brisk speeds.

**CARRY CAPACITY**

As shown in Table 2, the OTFL group performed the 25-ft carry test at significantly lower capacity than their intact counterparts. Furthermore, those in the OTFL group also reported greater pain ($P = 0.046$) during this test.

However, as per *Dictionary of Occupational Titles* standards, the OTFL and control groups can be categorized to carry a distance of 15 ft at the light-to-medium duty level of physical demand. To the authors’ knowledge, this was the first controlled study that described 25-ft carry testing as per federal standards performed by walking-age otherwise healthy men with unilateral OTFL loss.

**RECOMMENDATIONS**

The performance deficits demonstrated by this small group (n = 6) with OTFL suggest that the participants may be at risk for work-related risk of injury at the time of initial gait and carry testing. The investigators recommend a more expanded study to determine differences in gait speed between conventional and osteomyoplastic TFL groups using a 10-m walk test, to determine gait speed by surgical approach and minimize influence from fatigue.

In addition, risk of injury has been linked to spatiotemporal variability in gait performance during gait (differences in timing, cadence, step speed, step length, stride length, time in double support, etc.), as well as distance walked or gait speed. To better understand the spatiotemporal changes over time (e.g., 1 year), investigation of variability in gait performed by those with OTFL is warranted.

Another factor on which to direct future study is the actual rehabilitation after amputation. All with OTFL in the current study underwent “standard” rehabilitation. The authors recommend further investigation of work-related performance linked to rehabilitation approach, by working-age persons with either traditional or OTFL loss.

**REFERENCES**