BRIEF REPORT

# Quantifying the Effects of Body Mass Index on Safety: Reliability of a Video Coding Procedure and Utility of a Rhythmic Walking Task

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**Objectives:** To evaluate the association between body mass index (BMI) and motor actions related to safety risks (primary aim), and to examine the reliability of a video coding procedure and the utility of a rhythmic walking task in identifying safety risks (secondary aims).

**Design:** Using a cross-sectional design, participants were filmed during a rhythmic walking task at slow, normal, and fast audio metronome paces. A video coding procedure was used to quantify signs of safety risks from the videotaped sessions.

**Setting:** Motor development laboratory in a university.

**Participants:** Adults (N=32) with normal (n=15) and overweight (n=17) BMI scores participated.

**Interventions:** Not applicable.

**Main Outcome Measures:** Chi-squared analyses were conducted to compare the occurrence of coded motor actions (forward and lateral tripping) between participants with normal and overweight BMI scores. A kappa coefficient was computed as a measure of interrater reliability on the video codes.

**Results:** Participants who were overweight exhibited more safety risks compared with participants with normal BMI scores at the slow ($\chi^2_{1,N=32}$=3.94, $P$<.05, $d$=.75) and fast ($\chi^2_{1,N=32}$=3.85, $P$<.05, $d$=.74) metronome paces. Interrater reliability was high ($\kappa$=.90, $P$<.01).

**Conclusions:** In support of the primary aim, the findings show a relationship between overweight BMI scores and safety risks. Toward the secondary aims, the results demonstrate that a video coding procedure can be reliably used to assess safety risks and that creating tasks appropriate for assessing safety risks in overweight adults is needed.

**Key Words:** Body mass index; Obesity; Psychomotor performance; Rehabilitation; Safety.



IN THE UNITED STATES, over two-thirds of adults have body mass indexes (BMIs) in the overweight range (ie, BMI≥25kg/m$^2$ and <30kg/m$^2$).[1] Overweight BMI is linked to impaired gait. Compared with adults with a normal BMI, adults with overweight BMI decrease velocity, increase foot contact with higher double support and stance times, and shorten steps with decreased stride lengths. These gait differences may decrease stability owing to impaired balance and are related to increased safety risks: falls and injuries incurred from falling.[2] Adults who are overweight fall twice as often as adults with normal BMI and are more likely to sustain injuries needing medical attention.[3]

Limited research has assessed and quantified safety risks in overweight adults. Current assessments are geared toward older adults[4] and may be inappropriate for independently mobile overweight adults. Instead, their increased risks may be more apparent during tasks with accuracy or timing constraints. Clinicians and researchers have also used video assessments to quantify gait, but not safety risks. Assessing gait safety with video may be advantageous for comparing performance before and after interventions.[5]

Interventions to decrease falls also focus on older adults. Rhythmic step training has improved older adults' ability to time steps and consequently to recover balance before falling.[6] Such interventions may decrease safety risks for overweight adults, but to our knowledge, no studies have tested this assumption. The primary purpose of this study is to assess and quantify safety risks for adults with normal and overweight BMI.

## METHODS

### Participants

Participants were Boston University volunteers. Inclusion criteria were that participants be 18 to 60 years old, be free of cardiac, visual, and neuropathic conditions, and have BMI scores in normal or overweight ranges. Thirty-two participants were divided into 2 BMI groups. Fifteen participants had normal BMI, and 17 had overweight BMI (table 1).

### Rhythmic Walking Task and Room Setup

After giving informed consent, participants answered questions about their history of leg injuries (ie, whether they had sustained fractures or leg injuries that required medical attention). The experimenter (S.G.) took participants' weight and height to calculate BMI (in kg/m$^2$).

**List of Abbreviations**

| | |
|---|---|
| BMI | body mass index |
| bpm | beats per minute |

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**Table 1: Demographic Information**

| Participant No. | Age (y) | BMI (kg/m²) | Leg Injury |
|---|---|---|---|
| Participants With Normal BMI Scores | | | |
| 1 | 23.51 | 20.73 | N |
| 2 | 23.96 | 23.87 | N |
| 3 | 23.17 | 22.50 | N |
| 4 | 24.67 | 21.55 | N |
| 5 | 19.72 | 19.00 | N |
| 6 | 23.42 | 21.44 | N |
| 7 | 22.53 | 23.35 | N |
| 8 | 21.59 | 24.85 | N |
| 9 | 54.55 | 23.36 | N |
| 10 | 56.00 | 24.94 | N |
| 11 | 21.69 | 20.83 | N |
| 12 | 23.09 | 24.77 | N |
| 13 | 23.41 | 22.02 | N |
| 14 | 33.88 | 23.19 | Y |
| 15 | 30.22 | 23.79 | N |
| Mean ± SD | 28.36±11.47 | 22.68±1.73 | NA |
| Participants With Overweight BMI Scores | | | |
| 1 | 23.04 | 25.08 | N |
| 2 | 21.76 | 26.77 | N |
| 3 | 22.24 | 25.96 | N |
| 4 | 24.99 | 27.38 | N |
| 5 | 25.81 | 25.51 | N |
| 6 | 22.91 | 25.24 | N |
| 7 | 32.26 | 25.53 | Y |
| 8 | 23.45 | 27.43 | N |
| 9 | 23.76 | 25.90 | N |
| 10 | 23.36 | 28.29 | N |
| 11 | 23.46 | 27.51 | N |
| 12 | 22.88 | 26.55 | N |
| 13 | 29.07 | 26.69 | Y |
| 14 | 34.64 | 26.69 | N |
| 15 | 29.67 | 25.90 | N |
| 16 | 33.79 | 26.37 | N |
| 17 | 20.93 | 25.71 | N |
| Mean ± SD | 25.77±4.39 | 26.38±0.90 | NA |

Abbreviations: N, no; NA, not applicable; Y, yes.

The rhythmic walking task measured participants' ability to safely modify their gait to meet a constraint: walking to the pace of an audio metronome. Sessions occurred on a 6-m-long path videotaped from frontal and sagittal views. Participants were instructed to match their gait to the metronome by making heel contact at each beat. Each participant walked for 56 trials in 5 blocks: 10 initial and 10 final baseline trials at a self-selected pace, and 10 trials each at counterbalanced slow, normal, and fast metronome paces, with 2 intermediate baseline trials after each pace. The normal pace, 100 beats per minute (bpm), was based on the average adult cadence (steps per minute).[7] Slow (75bpm) and fast (125bpm) paces were 25% slower and faster than 100bpm, respectively. The Boston University Institutional Review Board approved all procedures.

### Video Coding Procedure

The video coding procedure quantified whether participants demonstrated safe gait modifications to meet the paces. Development of the procedure occurred in 3 steps. First, experimenters identified actions to code based on predictors of fall risks: forward and lateral tripping. Forward tripping relates to decreased foot clearance, and lateral tripping is associated with a decrease in the lateral distance between feet (step width). Both are predictors for falling.[8,9] Second, identified actions were operationalized. With forward tripping, participants' feet failed to clear the ground while swinging forward. Lateral tripping was defined as stepping over the standing leg with the swinging leg. Last, operational definitions were used to code occurrences of motor actions with a computerized video coding system[10] (fig 1). The system includes a controller linked to concurrent views of the video and a spreadsheet on the computer screen. Users selected trial start and end times, which automatically created a cell containing selected times in the spreadsheet. Within cells, users typed comments about motor actions. The primary coder (S.G.) scored trials for motor actions. Two secondary coders (A.N. and another), blinded to the primary coder's responses, scored each trial for reliability.

## RESULTS

Table 1 shows participants' demographics. We calculated percents for motor actions by dividing each action average by total action averages at each pace (eg, average lateral trips/[average lateral + forward trips] at 100bpm). Lateral trips included 86.96% at 100bpm, 100% at 75bpm, and 69.23% at 125bpm. Forward trips were 13.04% at 100bpm, 0% at 75bpm, and 30.77% at 125bpm.

Chi-square tests were conducted at each pace to compare the relationship between BMI and motor actions. At 75bpm, 33% of the participants with overweight BMI exhibited lateral tripping compared with no participants with normal BMI ($\chi^2_{1,N=32}=3.94$, $P<.05$, $d=.75$). At 125bpm, 17.65% of overweight participants exhibited lateral tripping compared with no participants with normal BMI ($\chi^2_{1,N=32}=3.85$, $P<.05$, $d=.74$). We found no significant differences between BMI and lateral tripping at 100bpm ($P>.05$).

To ensure that leg injuries did not drive associations between BMI and motor actions, additional chi-square tests were run. Leg injuries were unrelated to BMI and lateral tripping (all $P$s$>.05$, $d=.14$). However, they were related to forward tripping ($\chi^2_{1,N=32}=10.03$, $P<.01$, $d=1.35$). Accounting for metronome paces, there were no significant differences in leg injuries and motor actions at 75bpm or 125bpm ($P>.05$). At 100bpm, participants with overweight BMI who had leg injuries had a higher likelihood of exhibiting forward tripping ($\chi^2_{1,n=17}=7.97$, $P<.01$, $d=1.9$). A correlation between BMI and forward tripping partialling out effects of leg injuries revealed an insignificant result ($P>.05$).

Coders achieved high interrater reliability. At all trials, coders were in high agreement ($\kappa=.90$, $P<.01$).

## DISCUSSION

The primary purpose was to evaluate the relationship between BMI and safety risks. Secondary aims were to examine the reliability of a video coding procedure and utility of a rhythmic walking task. Participants were filmed as they walked to slow, normal, and fast metronome paces. During the walking task, participants with overweight BMI demonstrated more forward and lateral tripping at slow and fast metronome paces compared with participants with normal BMI. Results showed high interrater reliability.

Adults who were overweight had difficulty safely meeting a constraint. At both 75bpm and 125bpm, overweight partici-

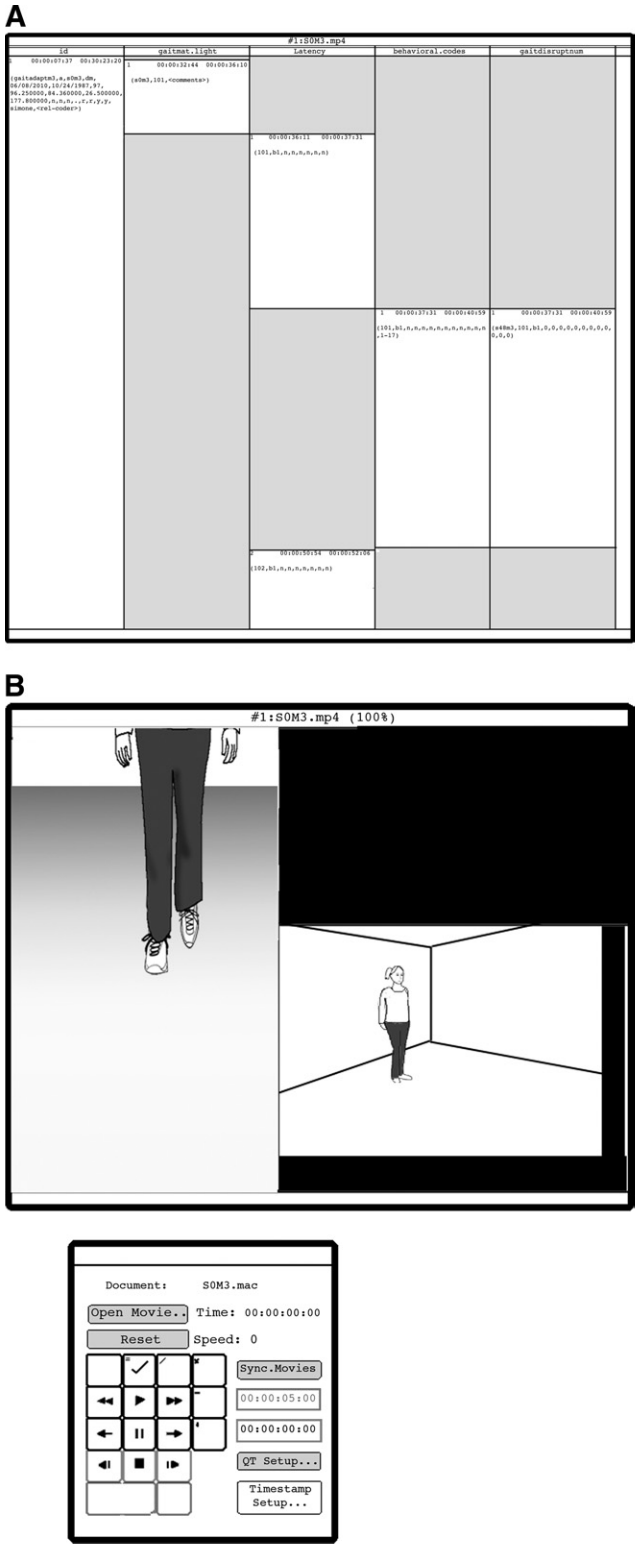


**Fig 1. (A) Computerized video coding system spreadsheet. This is a depiction of the spreadsheet that coders saw on the computer screen while scoring videotaped sessions. (B) Computerized video coding system video feed and keyboard controller. This shows the video and keyboard controller that were visible to coders concurrent with the spreadsheet during coding. The video controller on the bottom was linked to the number pad on a computer keyboard. Pressing specific numbers on the keyboard either controlled the video shown above or created cells in the spreadsheet in panel A.**

pants exhibited lateral tripping. Increased lateral tripping may reflect sacrificing walking safety to meet constraints. Therefore, the results highlight the importance of finding appropriate tasks to examine safety risks in overweight adults. Partialling out effects of leg injuries yielded an insignificant relationship between BMI and forward tripping; narrowing step width may increase safety risks for those with overweight BMI more than decreasing foot clearance.

### Study Limitations

Limitations include the following: (1) nonindividualized metronome paces, (2) an inability to establish cause and effect between leg injuries and forward tripping with a cross-sectional study, and (3) excluding participants with cardiopulmonary disease, visual loss, or peripheral neuropathy. This was the first step in measuring and quantifying safety risks in adult populations. Follow-up studies to address these limitations are currently underway.

## CONCLUSIONS

Heightened safety risks for adults who are overweight decreases participation in weight loss interventions to live active, healthy lives. Assessing and quantifying their safety risks can help clinicians and researchers to improve overweight adults' ability to be safe in their environments.

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