

Assessment of postural sway during multiple load and visual conditions

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Introduction

- Firefighters (FF) are at high risk of falling at fire ground.
- One of leading causes of injury on the fire ground is loss of balance and falls.
 - Fire grounds are hot, smoky, and slippery.
 - FFs wear personal protective equipment (PPE) and self-contained breathing apparatus (SCBA).
 - PPE and SCBA are insulated and heavy.
 - The heaviest part is air bottle.



Related studies

- Load carriage and visual inputs affect balance in non-firefighter groups.
- Schiffman et al. found that load carriage on back significantly reduces balance. As weight increased, balance decreased.
- Collins et al. found that visual input significantly improves balance.

Purpose of this study is

- To investigate the effect of bottle configuration (weight and size) on balance of firefighters.
- To investigate the effect of visibility on balance of firefighters.

Air bottle configuration

- Aluminum (AL)
- Fiber glass (FG)
- Carbon fiber (CF)
- Redesigned (RD)

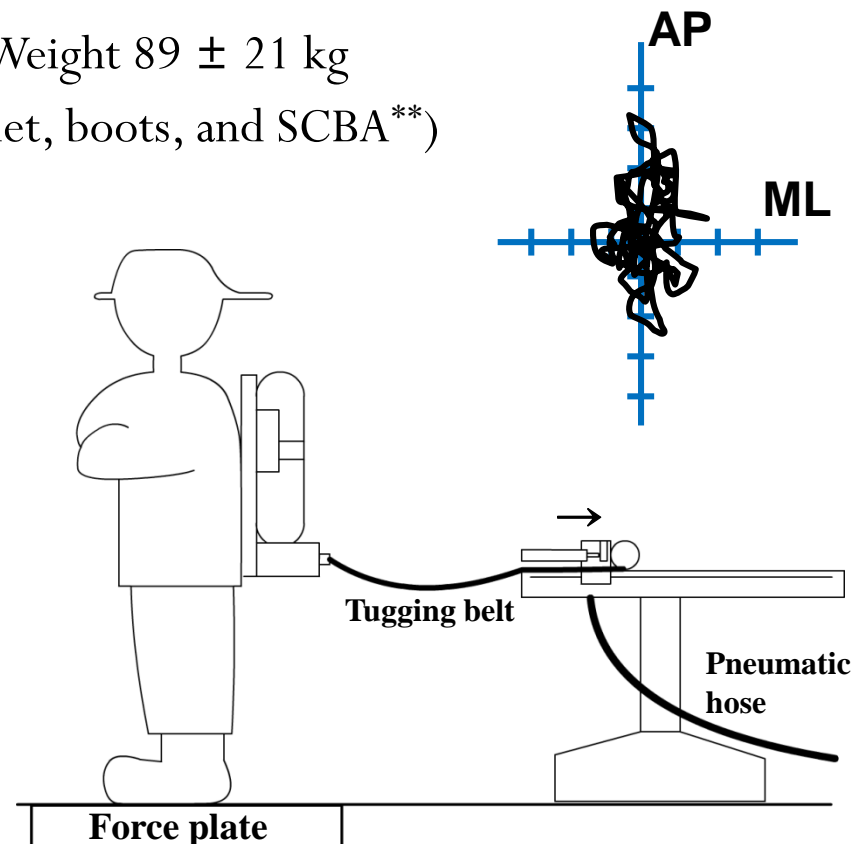


	Diameter (cm)	Length (cm)	Weight (kg)	Cost
Aluminum	17.2	59.7	9.1	Cheap
Fiber glass	14.0	57.2	9.1	Custom-made
Carbon fiber	14.0	54.6	5.4	Expensive
Redesigned	19.0	39.4	5.4	Custom-made

Subjects and Protocols

- Subjects
 - 23 male firefighters
 - Age 28 ± 5 yrs, Height 177 ± 8 cm, Weight 89 ± 21 kg
 - Wore PPE* (bunker coat, pants, helmet, boots, and SCBA**)
- Protocols

Bottle (AL, FG, CF, RD)	
Eyes Open	Eyes Closed
3 Quiet Stance	3 Quiet Stance
7 Tug	7 Tug
Randomized	Randomized
60s each trial	60s each trial



*PPE : Personal Protective Equipment

** SCBA : Self-Contained Breathing Apparatus

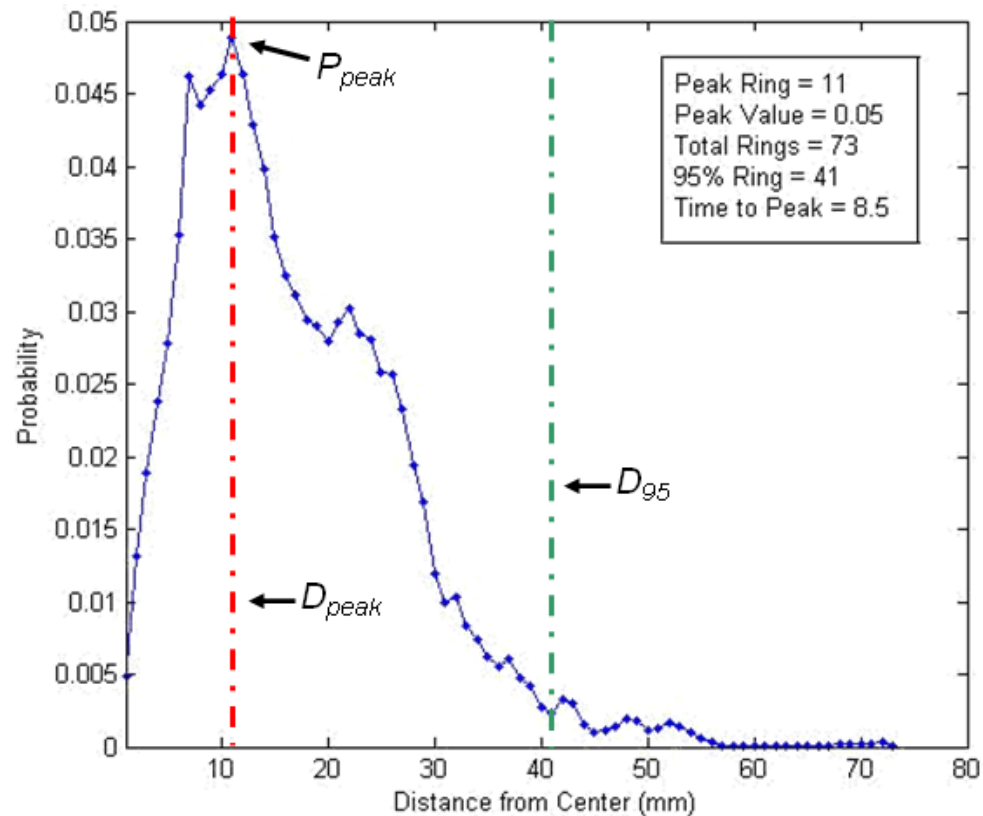
Traditional stabilometric parameters of COP (TRAD)

- Maximum distance (*MaxDist*)
- Standard deviation of displacement (*SD*)
- Range of trajectories (*Range*)
- Mean frequency (*MF*)
- Mean velocity (*MeanVel*)
- 95% Frequency(*Freq95*)
- Angular deviation from AP axis (*AngDev*)

All parameters in both AP and ML directions

Invariant density analysis (IDA)

- Dynamics of COP is represented by Markov chain
- Markov model is a reduced model of dynamics.
- Peak probability of ID plots (P_{peak})
- Distance to peak location (D_{peak})
- Distance to location of 95% area (D_{95})
- Time to reach invariant density (T_{inv})

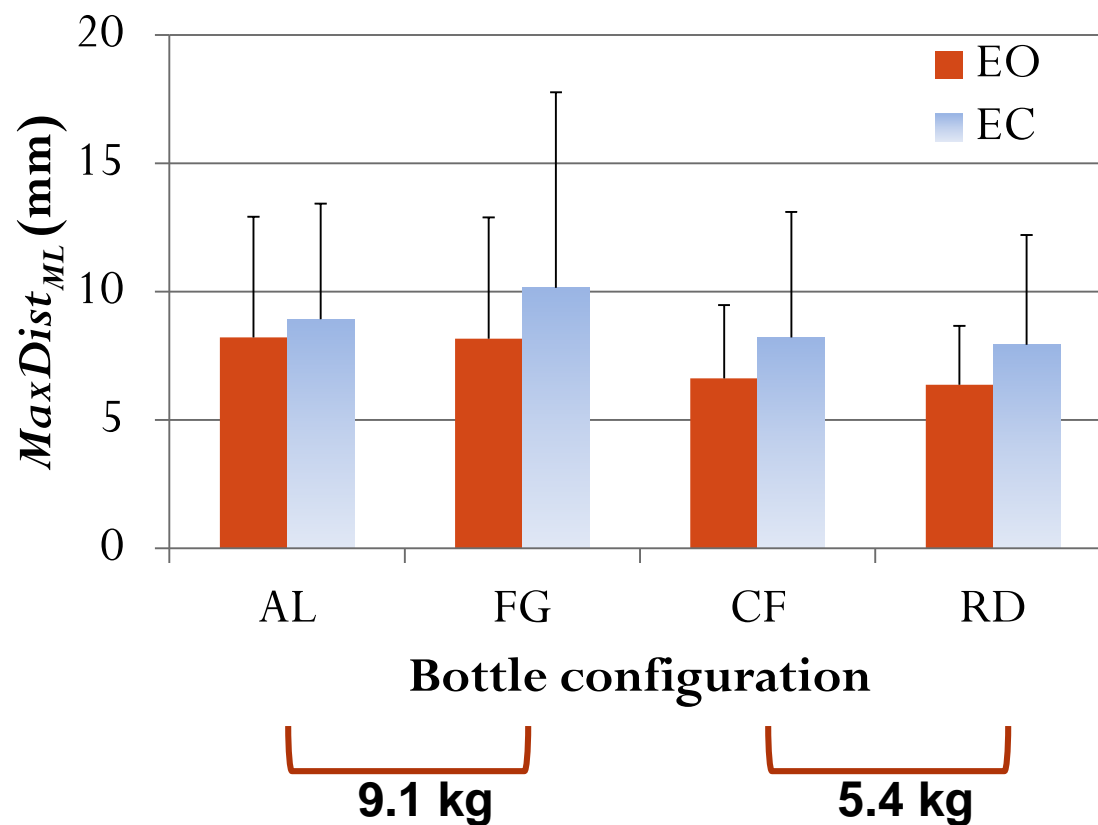


All in both AP and ML

TRAD results

- Four parameters were significantly different by condition
 - $MaxDist_{ML}$ ($p < 0.001$)
 - SD_{ML}
 - $Range_{ML}$
 - $MeanFreq_{ML}$
- Weight of bottle significantly affected balance.
- Size of bottle did not significantly affect balance.
- Balance was significantly affected only in ML direction.
- Visual input significantly contributed to balance.
- No interaction between bottle configuration and visual input.

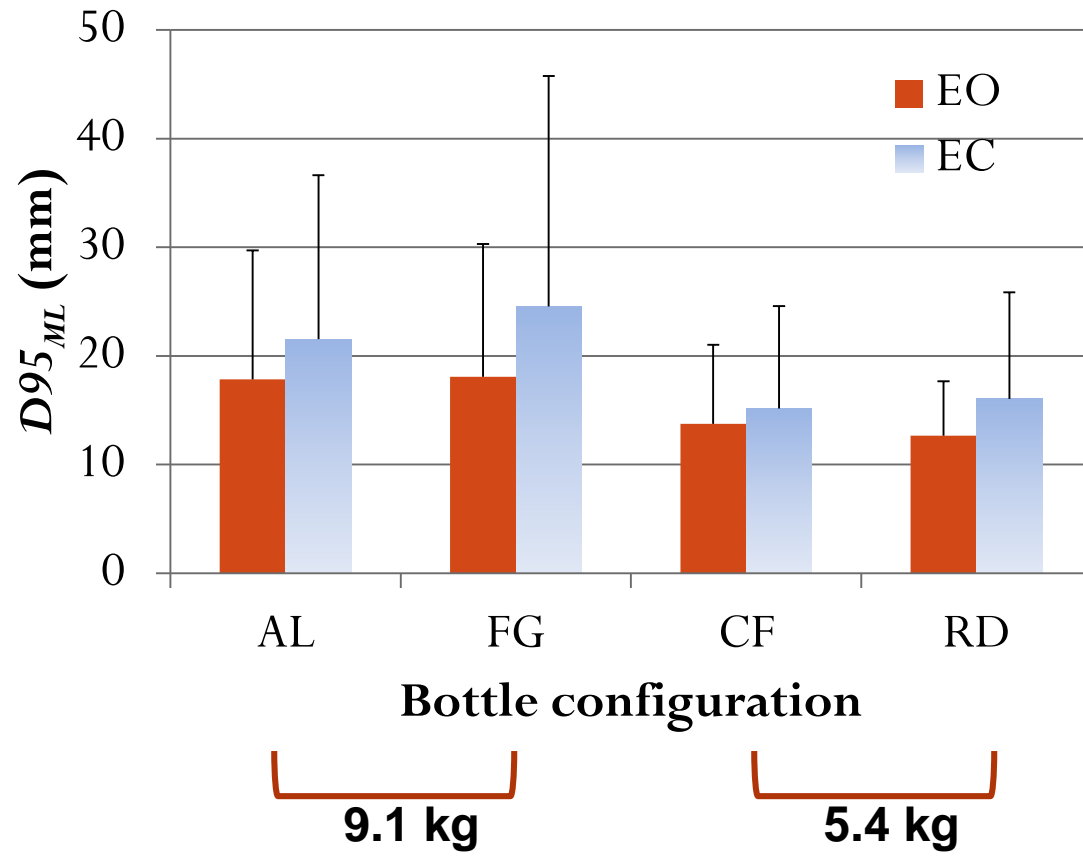
TRAD results - $MaxDist_{ML}$



IDA results

- Two parameters were significantly different by condition.
 - P_{peakML}
 - D_{95ML}
- Weight of bottle significantly affected balance.
- Size of bottle did not significantly affect balance.
- Balance was significantly affected only in ML direction.
- Visual input significantly contributed to balance.
- No interaction between bottle configuration and visual input.

IDA results – D_{95ML}



Discussion

- Reducing the weight of bottle significantly reduced postural sway in ML direction.
 - Reducing weight of bottle is important for the safety of firefighters.
 - Need to perform system identification to better understand balance mechanism in ML direction.
- Size of bottle is not as important as weight of bottle.
 - Varying the size of bottle in this study only changed the position of the whole body COM by less than 2% .

Conclusions

- Currently available light-weight carbon fiber air bottles significantly increase postural stability compared to current heavy-weight aluminum air bottles.
- Redesigning the air bottle to be shorter and located lower on the back does not affect postural stability.
- Visual condition also significantly affects postural stability of individuals wearing added load.

Acknowledgement

- [illegible]