Statistical prediction of hand-load carrying strategy and load level from wearable inertial sensor data

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Objective

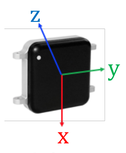
To develop and validate a statistical prediction algorithm that uses body-worn inertial sensor data for classifying load carrying strategy and load-level in workers.

Motivation

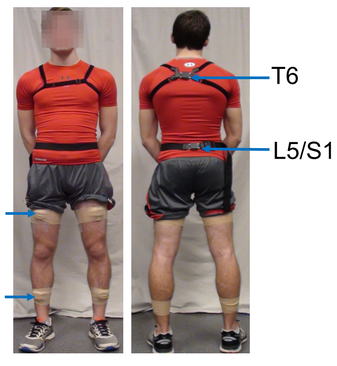
- Work tasks such as carrying heavy hand-loads often and over long durations are known risk factors for low back disorders in workers.
- Work-related overexertion events, dominated by low back disorders and pain, cost the US $13.8 billion each year [1].
- Measuring workers exposures to carrying is an important step towards managing and reducing the prevalence of low back disorders.

Methods

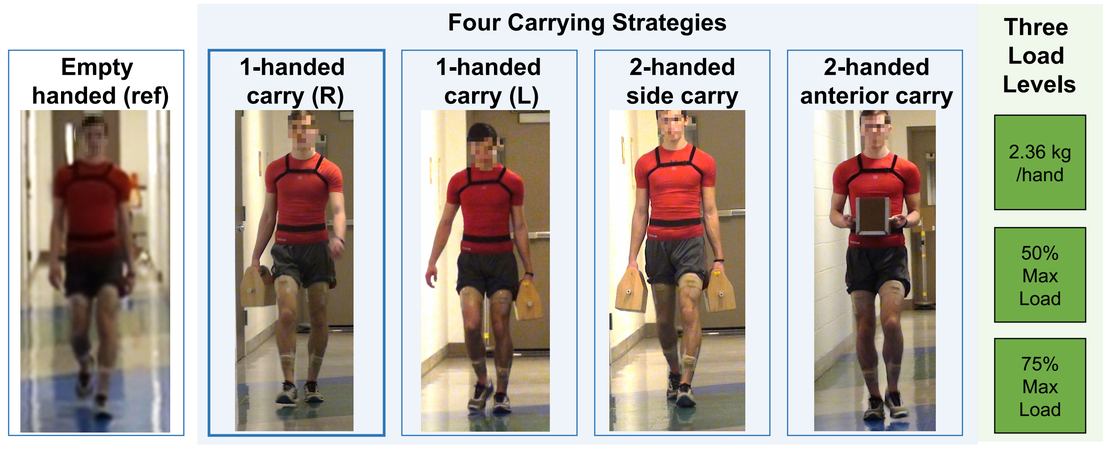
1 Instrumentation



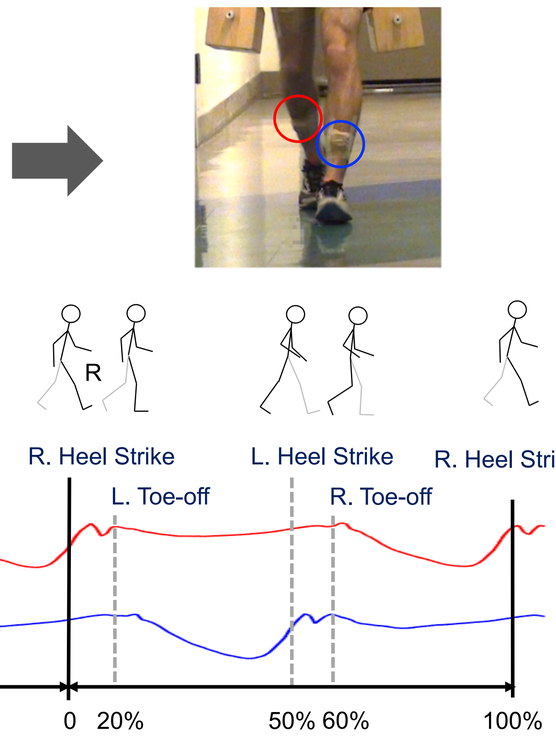
Inertial sensor
(APDM Inc.)
Sampling freq.: 80 Hz



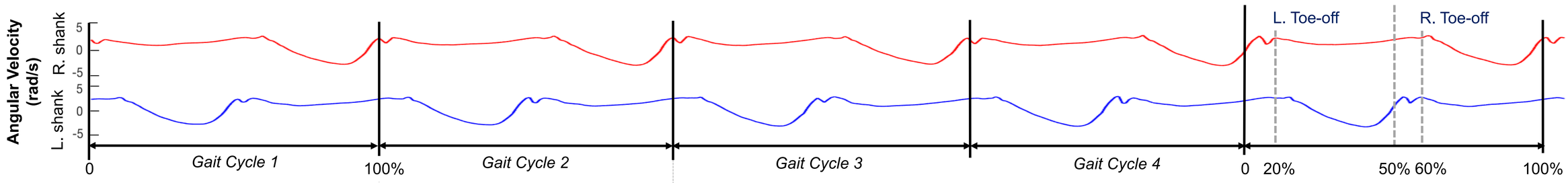
2 Collected data from 10 right-handed males in simulated carrying tasks



3 Algorithmically detect gait events from inertial sensor data [2]

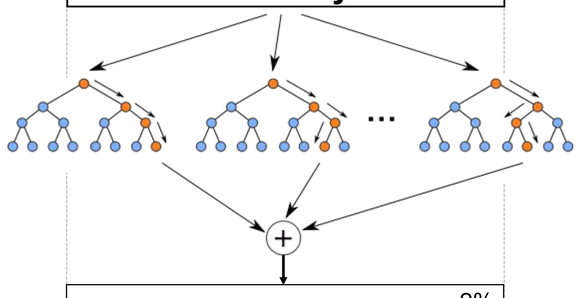


Sample gait trajectory

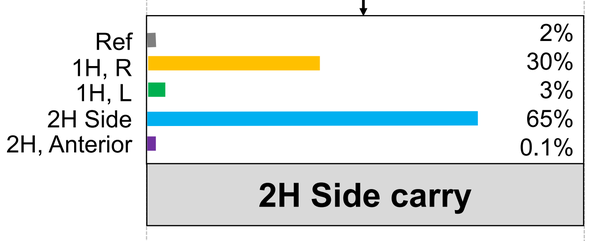


4 Compute predictor variables = 24 Gait parameters for each cycle

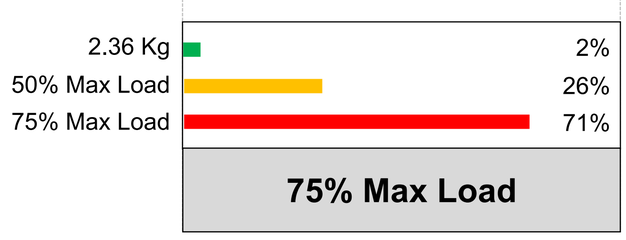
5 Implemented Random Forest [3]



6 Predict Carrying Strategy [stage 1]



7 Predict Load Level [stage 2]



Model Performance

Based on 10-fold holdout cross-validation repeated 20 times

Table 1. Accuracy of predicting strategy (95.0%)

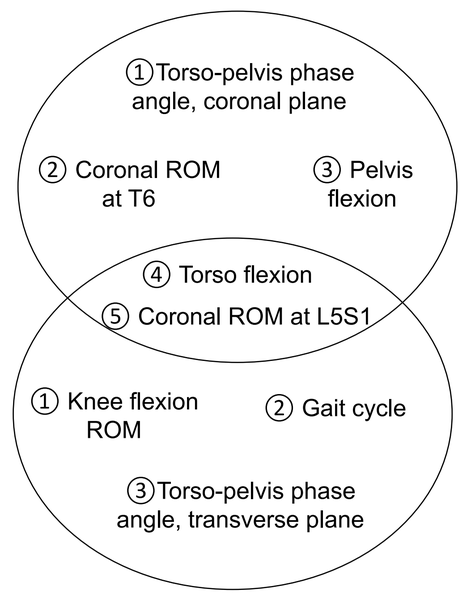
Predicted strategy \ Actual strategy	Ref	1H, R	1H, L	2H side	2H Ant
Ref	38	0	0	0	0
1H, R	4	109	1	2	0
1H, L	0	3	67	3	4
2H side	1	1	1	88	3
2H Ant	1	0	0	0	152

Table 2. Accuracy of predicting load within 2H side carry (95.7%)

Predicted load level \ Actual strategy	2.36 kg	50% Max	75% Max
2.36 kg	22	1	0
50% Max	0	21	0
75% Max	0	2	24

Model Interpretation

Top 5 important variables for carrying strategy (top) & loads (bottom)



Conclusions

- A two-stage random forest algorithm correctly classified the carrying strategy and load level in 389 out of 478 (81.3%) gait cycles
- Wearable sensor data combined with statistical prediction demonstrate strong potential for measuring workers exposures to physically demanding tasks over time.
- Our goal is to develop low-cost personalized tools for assessing physical workload and injury risk in workers engaged in physical labor.

References

[1] Liberty Mutual Inc. (2017). 2017 Liberty Mutual Workplace Safety Index. *Annual Report of Scientific Activity.* Hopkinton, MA.
[2] Aminian, K., Najafi, B., Büla, C., Leyvraz, P.-F., & Robert, P. (2002). Spatio-temporal parameters of gait measured by an ambulatory system using miniature gyroscopes. *Journal of Biomechanics*, 35(5), 689-699.
[3] Breiman, L., Friedman, J. H., Olshen, R. A., & Stone, C. J. (1984). Classification and regression trees. Wadsworth & Brooks. *Monterey*, CA.

This study was supported by NIDILRR (Grant # 90IF-0094-01-00).
NATIONAL INSTITUTE ON DISABILITY, INDEPENDENT LIVING, AND REHABILITATION RESEARCH NIDILRR [IOF-2 010]