Predicting hand-load carrying strategy and load level from gait kinematics obtained from wearable inertial sensor

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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.

Conclusions

- A two-stage random forest algorithm correctly classified the carrying strategy and load level in 15 out of 159 (90.6%) walk trials.
- 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.

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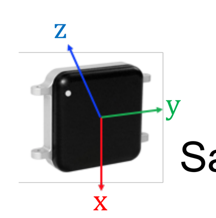
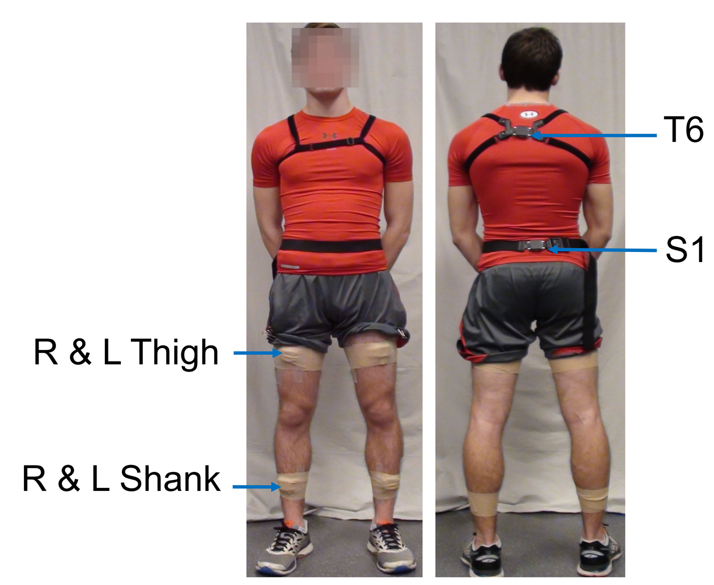
Methods

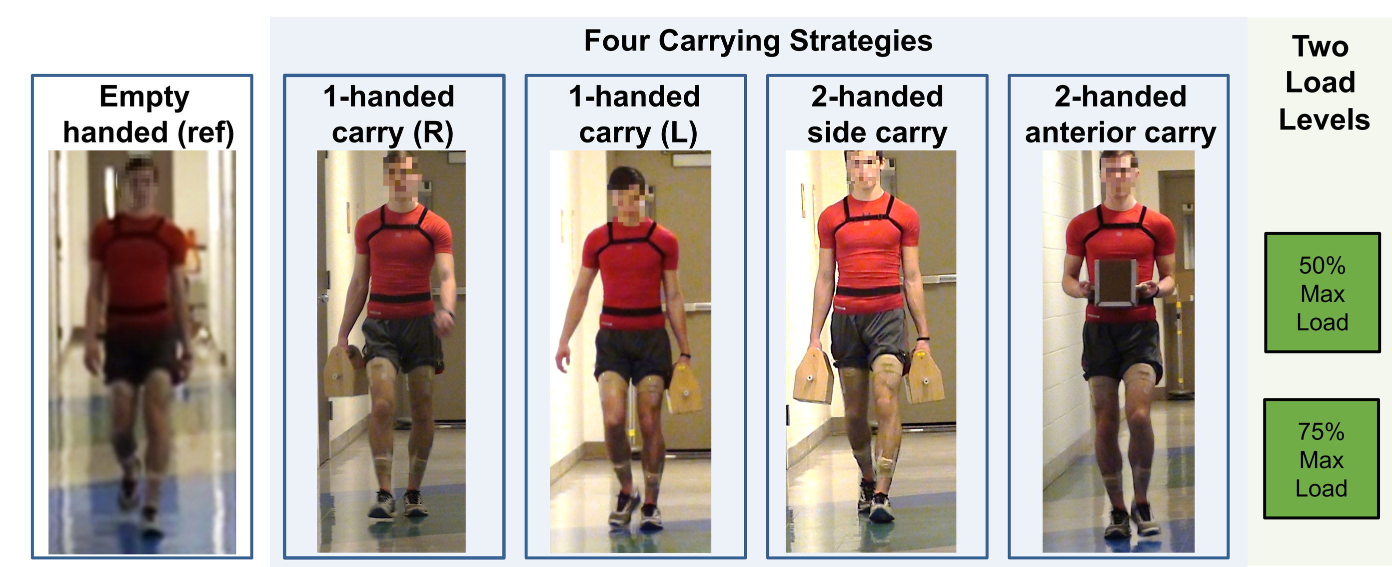
❶ Instrumentation



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

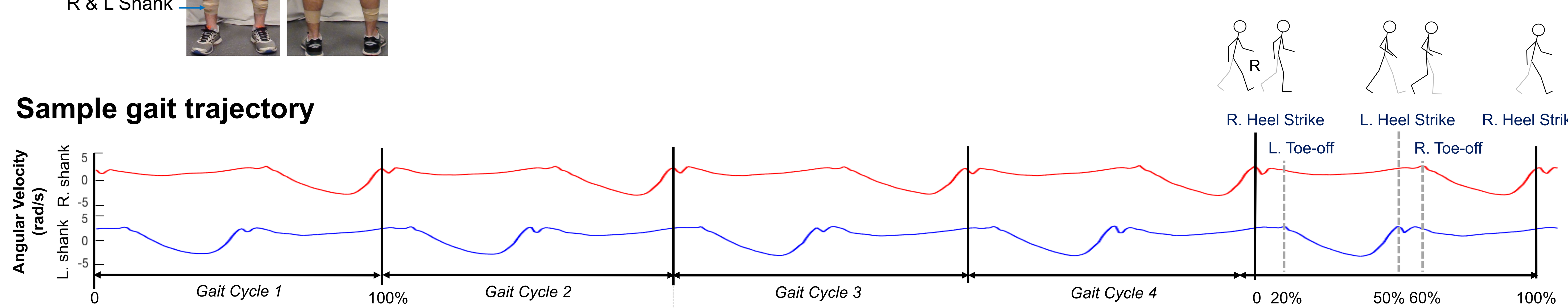


❷ Collected data from 9 right-handed men in simulated carrying tasks



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

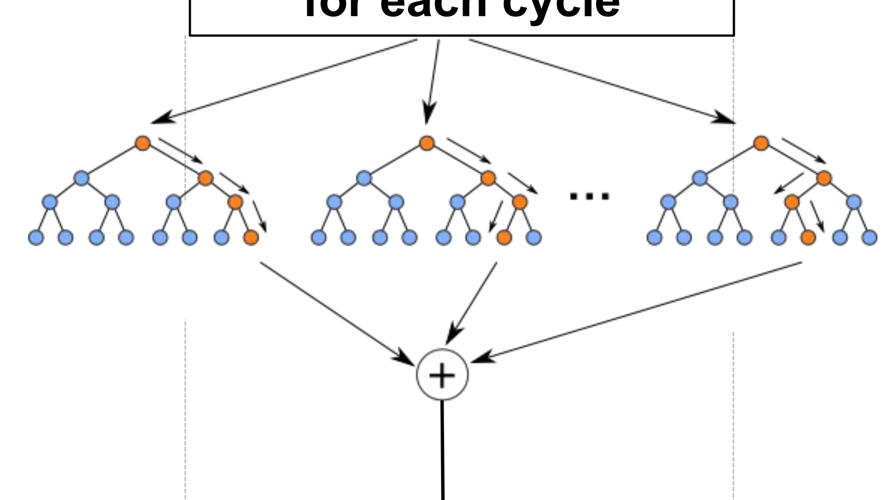
Sample gait trajectory



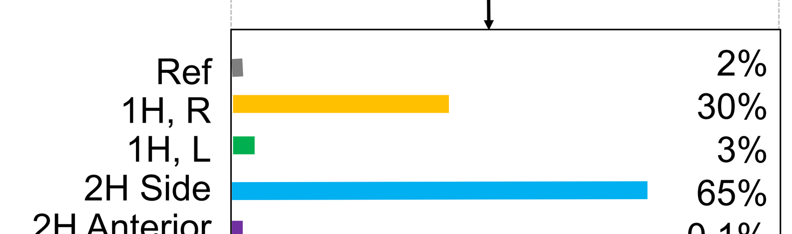
❹ Compute predictor variables =

13 Gait parameters for each cycle

❺ Implemented Random Forest [3]

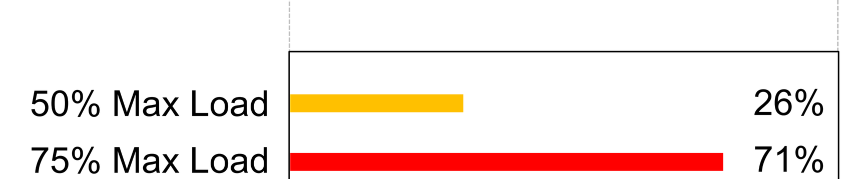


❻ Predict Carrying Strategy [stage 1]



2H Side carry

❼ Predict Load Level [stage 2]



75% Max Load

Model Performance

Based on 10-fold cross-validation test

Table 1. Accuracy of predicting strategy (96.9%)

		Predicted Carrying Strategy						
		Ref	1H, R	1H, L	2H Side	2H Ant	Total Walk Trials	Sensitivity
Actual Carrying Strategy	Ref	18	0	0	0	0	18	100 %
	1H, R	0	32	3	0	0	35	91.4%
	1H, L	0	2	33	0	0	35	94.3%
	2H Side	0	0	0	36	0	36	100 %
	2H Ant	0	0	0	0	35	35	100 %
Total Walk Trials		18	34	36	36	35	159	
Precision		100%	94.1%	91.7%	100 %	100%		

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

		Predicted Load Level			
		50% Max	75% Max	Total Walk Trials	Sensitivity
Actual Load Level	50% Max	17	1	18	94.4%
	75% Max	1	17	18	94.4%
Total Walk Trials		18	18	36	
Precision		94.4%	94.4%		

Model Interpretation

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