Calories Burnt by the Treadmill and the Apple Watch Series 4

Should they be trusted?

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Abstract

The purpose of this study is to assess how accurate the Apple Watch Series 4 and treadmill is when determining the amount of calories burnt during exercise. A Machine Learning tool was created to predict calories burnt.

Participant Characteristics

MALE PARTICIPANTS

Characteristics	Mean ± SD
Age (years)	21.93 ± 1.33
Weight (kg)	79.95 ± 11.20
Height (in)	70.79 ± 2.70

FEMALE PARTICIPANTS

Characteristics	Mean ± SD
Age (years)	21.29 ± 1.67
Weight (kg)	66.47 ± 7.88
Height (in)	65.43 ± 1.59

Glossary

MET: A unit of measure of the rate at which the body expends energy that is based on the energy expenditure while sitting at rest and is equal to 3.5 milliliters of oxygen per kilogram of body weight per minute, also called metabolic equivalent task.

Calorimetry: The science or act of measuring changes in state variables of a body for the purpose of deriving the heat transfer associated with changes of its state.

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ML Model - XGBRegressor

Model Overview:
- XGBoost Regressor
- Predicts accuracy of treadmill calories burnt
  (Provides multiplier for treadmill readings)

Key Features:
- Utilizes gradient boosting
- Prediction is a sum of weak learners
  (decision trees), with weights determined
  by gamma at each leaf node
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Results

The Apple Watch Series 4 (for 3 minutes) **tended to underestimate the number of calories burnt** while the treadmill stated (regardless of participants weight) that they burned calories ranging from 33-39 calories which infers **the treadmill burns calories according to one person's body weight**. The Apple Watch 4 had a percent error range of (0.30% - 26.74%) for Male participants with a Mean Average Percent Error (MAPE) of 11.74%. For Female participants, the percent error range was (4.52 - 27.53%) with a MAPE of 17.84%. These two MAPE ranges coincide with a 2023 study in which experiementers found that the Apple Watch Series 6 had a MAPE range of (9.71 - 32.81%). **The ML model was able to predict the actual calories burnt with the greatest accuracy, averaging ±1.5% error.**

References

- Ferrara, Cynthia M., et al. "Caloric Expenditure Using Indirect Calorimetry, Apple Watch Sport, and Fitbit Zip." Journal of Exercise Physiology, June 2017, www.asep.org/asep/asep/JEPonlineAPRIL2015_Ferrara.pdf.
- Kaminski, Jacqueline. "Metabolic Equivalents: What Are They & How to Calculate Them." NASM, blog.nasm.org/metabolic-equivalents-for-weight-loss, Accessed 1 Apr. 2024.
- "Met." Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/met. Accessed 1 Apr. 2024.
- Sun, Xinzheng, et al. "Validity of Apple Watch 6 and Polar A370 for Monitoring Energy Expenditure While Resting or Performing Light to Vigorous Physical Activity." Journal of Science and Medicine in Sport, 20 July 2023, www.jsams.org/article/S1440-2440(23)00043-9/fulltext.
- Wikipedia contributors. "Calorimetry." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 7 Nov. 2023. Web. 22 Apr. 2024.

Experiment

Fifteen adult males, aged approximately 21.93 ± 1.33 years, and seven adult females, aged approximately 21.29 ± 1.67 years, wore Apple Watch Series 4 while running on a treadmill for 3 minutes at 6 mph (9.67 km/h) with no incline change (MET value of 10.1). The study compared calories burned measured by the Apple Watch and treadmill display against a validated calorimetry formula (eq.1)

$$\text{Calories Burned} = \frac{\text{METS} \times 3.5 \times \text{Body Weight (in kg)}}{200} \quad (1)$$

$$F(x) = \sum_{i=1}^{n} f_i(x)$$

$$\mathcal{L}(y_i, \hat{y}_i) = |\ \text{Formula Calories - Treadmill Calories}\ |$$

$$\sum_{i=1}^{n} \hat{\gamma}_1 f_1(x) + \hat{\gamma}_2 f_2(x) + \ldots + \hat{\gamma}_n f_n(x)$$

$$\frac{d}{d\hat{y}_i}\mathcal{L}(y_i, \hat{y}_i) \rightarrow$$

Figure 1: The Model

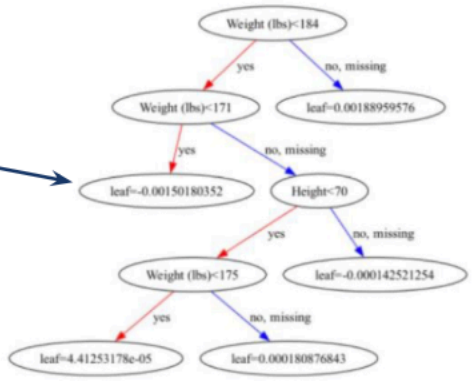

Figure 2: The Algorithm

Conclusion

Overall, the Apple Watch Series 4 is an extremely useful tool for everyday fitness and health tracking and is well worth the investment.

This device should only be used for an approximation for how many calories you are burning during various exercises and not to be taken with 100% certainty.