Title: Trunk posture during manual materials handling of beer kegs

The paper presents a quantitative assessment of trunk postures using an inertial measurement unit (IMU)-based kinematic measurement system while workers lifted kegs at a craft brewery. Further the paper present results of the LiFFT cumulative damage tool used to evaluate the task.

I like that the authors conducted a study in a real working environment and give recommendation for how to improve it.

Yet, there are several issue that I think should be addressed, for the paper to reach its full potential

I apologies to the authors I was not a reviewer on the first draft of the paper. Thus my comments are new to you. In my comments I try to address both ideas for directions that the paper could take, and some clarification.

I have referred to many references that I think could help address both, yet it is your paper so choose what you think is relevant.

* **Main issues:**

1. When the worker is also lifting a load estimating load on the back just form trunk posture is very difficult to do (this in some way the comment you have received in the first review). This led you to change the paper and add the LiFFT cumulative damage tool analysis to the paper. Yet it seems that you have not change much your Title, introduction or your abstract to account for this.

Further it seems that you are still focusing on trunk postures and not on evaluation of what are the risk for injury to the workers. Which I think is the more important question.

You could use tools such as recommend by the first reviewer, if you want to make it more specific you could try to use the IMU to do inverse dynamics (such as in these two papers).

G.S. Faber, C.C.Chang, I.Kingma, J.T.Dennerlein, J.H.vanDieën Estimating 3D L5/S1 moments and ground reaction forces during trunk bending using a full-body ambulatory inertial motion capture system. Journal of Biomechanics 49 (2016)

Validation of a wearable system for 3D ambulatory L5/S1 moment assessment

during manual lifting using instrumented shoes and an inertial sensor

suit, G.S. Faber, I. Kingma, C.C. Chang, J.T. Dennerlein, J.H. van Dieën, *Journal of Biomechanics 2020*

* **Specific Comments**
* To make it easier for you to find what my comment refer to I have add line number to you document (starting from 1 at each of the pages)

1. P3. Line 28 what is the height of the pallet and was this taken into account?

2. P3. line 29, “The vertical rail height of the roller conveyor was 169 cm from the floor “. This seems to be very high. Form the pictures it seems that the roller conveyor is at 90cm+-. Please mark on the picture where this measurement is.

2. P3. line 8 and 33 not sure numbers add up. How many people are working at the same time at this working station? if the “At peak efficiency, the kegging line throughput (clean and fill) varied from 144 to 160 half-barrel kegs per hour” this mean for 8-hour shift =1280 so for 600 there is a minimum of two people working together. Please explain in the manuscript.

3. P5. Line 12, if I understand correctly then each worker did 32 high 32 low lifts. It would be nice to also see this in the figures for the trunk angle during the tack (add standard deviation not just the average).

4. P5 Line 31-33 it is not clear how you define these angle (relative to what e.g. global reference frame or maybe hips). Wording and possibly figure will help (it could be in appendix). How do you define awkward postures and why (add reference)

5. P5. Table 1 min mass is 88.9 and max mass is 78.8 is this right?

6. P6. Table 1 is ankle height measured with or without shoes?

7. P6. Table 2. table name is not right it shows more than mean angles, further again in many cases the larger number is in the minimum column and the smaller value is in the maximum column. What is the mean angle and how do you calculate it (what interval...) further explain why is it important (if I understood this correctly, I don’t think it is that important as it is some proxy for average load, where the big factor is the peak force during the cycle?

8. p7. Are these figure for one lift or a mean of all the lifts? How different data form one worker to the other. What is the accuracy of your system in angels (should be in the method section)

9. P8 Line 8. From the pictures it seems that when the keg is far the worker pulls it and tips it toward him before lifting how did you model the force applied by the worker in such case. Or did you always assume the keg mass\* gravity (mg)

9. P8. Line 12-13 “The present study observed 64 lifts, which equates to 324 lifts per shift” how did you get to this number? How long did it take each of the workers to perform this tasks?

(64\*8=512)

10. P8 “For example, according to LiFFT, a worker who lifts an empty keg 324 times with a peak moment of 60 ft lbs (81.3 Nm)” while the torque value is reasonable acurading to recent publicantion that studies simller tasks.

*For moment*

Yaar Harari, Avital Bechar, Raziel Riemer 2020 Workers’ biomechanical loads and kinematics during multiple-task manual material handling, applied ergonomics

*For moments and lever arm*

Yaar Harari, Raziel Riemer, Avital Bechar 2019 Differences in spinal moments, kinematics and pace during single-task and combined manual material handling jobs. Applied ergonomics

it would be helpful to know how did you calculted these numbers (i.e. how did you obtained the lever arm and the load (what was the variability on those among the workers). You should be able to obtain this form the Xsens system and if not using forward kinmatics method(angles form the Xsens and segments legth as measured).

P9 line 15. again I would like to know how did you calulted this numbers 126ft.lb (alos please write in Nm too)

P10. Line 11-22 I like this recomndcation

Few papers that recommend change of the workers station and alos look at the prodcativty / money (this is alos relvent to page 12 line 12-18)

Das, B.; Sengupta, A. K. (1996). Industrial workstation design: a systematic ergonomics approach, *Applied Ergonomics*,

Battini, D.; Faccio, M.; Persona, A.; Sgarbossa, F. (2011). New methodological framework to improve productivity and ergonomics in assembly system design, *International Journal of Industrial Ergonomics*,

Cimino, A.; Longo, F.; Mirabelli, G. (2009). A multimeasure-based methodology for the ergonomic effective design of manufacturing system workstations, *International Journal of Industrial Ergonomics*

Longo, F.; Mirabelli, G. (2009). Effective design of an assembly line using modelling and simulation, *Journal of Simulation*, Vol. 3, No. 2, 50-60.

Del Rio Vilas, D.; Longo, F.; Monteil, N. R. (2013). A general framework for the manufacturing workstation design optimization: a combined ergonomic and operational approach, *Simulation*, Vol. 89, No. 3, 306-329,

Harari, Y., Bechar,A., and Riemer, R**.** 2019. Simulation-based optimization methodology for human-machine system design that maximizes productivity while considering ergonomic constraints. IEEE Transactions on Human-Machine Systems

Ben-Gal, I.; Bukchin, J. (2002). The ergonomic design of workstations using virtual manufacturing and response surface methodology, *IIE Transactions*,

Harari, Y., Bechar, A., Raschke, U., and Riemer, R. 2017. Automated simulation – based workplace design that considers ergonomics and productivity. *International Journal of Simulation Modelling*