PREDICTING L5-S1 COMPRESSION FORCES DURING DYNAMIC LIFTING TASKS: A LINEAR MODELING APPROACH

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Summary

This study aimed to develop a predictive model for estimating L5-S1 compression forces during dynamic manual handling tasks. Using data from 30 participants, the model incorporated temporal kinematics, neuromuscular responses, and anthropometric factors, with forces estimated via a musculoskeletal model assisted by optimization (EMGAO). Linear regression equations were created to predict these forces, showing strong predictive performance when validated on independent data. The findings highlight the importance of incorporating task-specific dynamic variables to better leverage the potential of advanced estimation models and, in turn, identify promising avenues for workplace analysis and injury prevention.

Introduction

Musculoskeletal disorders (MSDs), especially those affecting the lumbar spine, pose a significant concern in various industries, impacting nearly two-thirds of the workforce and causing substantial economic costs [1]. Manual material handling tasks heighten the risk of lower back injuries due to the lumbar region's critical role in force distribution, where mechanical loads can exceed tissue tolerance limits [2].
To address these risks, analytical models with different level of complexity have been developed to quantify joint forces, though their practical application remains limited [3]. Predictive equations improve model usability [4], but those based on static conditions fail to capture dynamic loading scenarios, as they lack temporal kinematic and neuromuscular factors key influences on joint load magnitude and distribution [5].
This study introduces a multiple linear regression model to estimate L5/S1 compression forces, incorporating temporal kinematics, neuromuscular responses, and individual-specific parameters to improve prediction accuracy and enhance the model's realism by considering factors with potential influence on compression forces.

Methods

Data for this study were taken from Plamondon et al. [6]. Thirty participants (10 women) with varying manual handling experience performed lifting and lowering tasks without specific technique instructions (Figure 1).

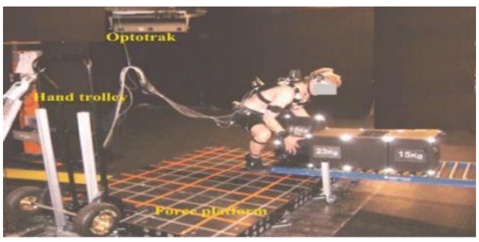

Figure 1 : Illustration of the experimental set-up

All had a low incidence of injuries, particularly in the lower back. L5/S1 joint forces were estimated using an EMG-assisted optimization model (EMG-AO) [7], and coactivation of six bilateral trunk muscle pairs (Longissimus Dorsi, Iliocostalis, Multifidus, Rectus Abdominis, External and Internal Obliques) was analyzed using the time-varying multi-muscle coactivation function (TMCf) [8].
A total of 1117 trials, each representing a single box displacement, were analyzed. Linear regression equations were developed using a forward stepwise approach with individual factors, kinematic variables, and trunk muscle coactivation indicators to predict EMG-AO model outcomes during lifting.
The dataset was split into a training set for model development and an independent validation set to assess predictive accuracy and generalizability on unseen data.

Results and Discussion

The model predicts maximum compression forces with an adjusted R^2 of 72 %, using 11 variables related to posture, temporal kinematics, anthropometry, and neuromuscular factors. Its predictive performance was evaluated using a validation dataset, where it accounted for 66% of the variability in maximum compression forces (Figure 2). Such a value is relatively performant compared to the values reported for other models when tested in a dynamic context [4,5].

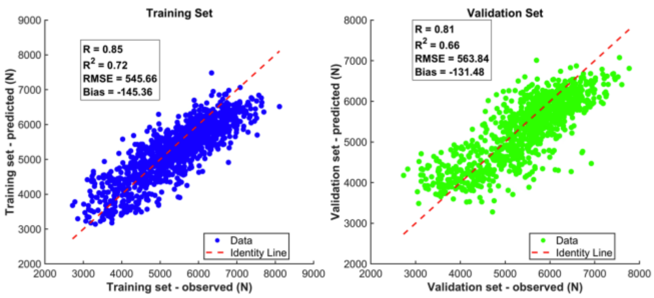

Figure 2 : Overall Model Performance and Distribution

Conclusion

By integrating key factors such as temporal kinematics and neuromuscular responses, the model provides insights into force distribution mechanisms at the L5-S1 joint. The presence of validation data set clearly demonstrated the effectiveness of the proposed model. Future research should refine the model's generalizability, particularly for individuals with low back pain and diverse handling contexts.

References

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