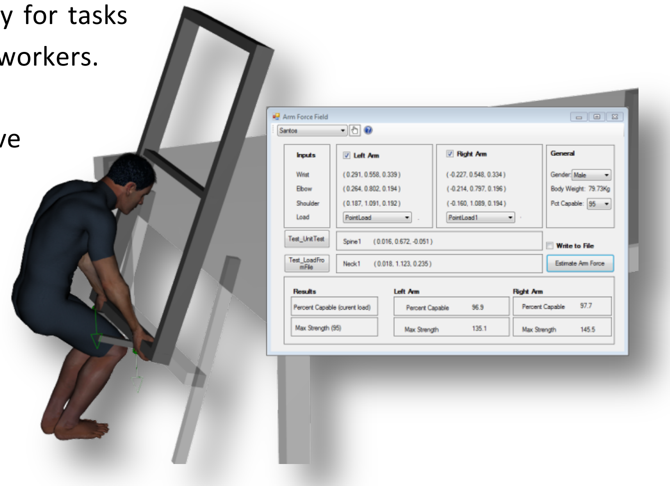
SANTOSHUMAN®

Predicting Exposure to Risk of Injury

Estimates are that every year in the USA, 2.8 Million workers suffer a serious **job-related injury or illness costing US employers $50B – $70B per year in compensation**. In addition, the greatest cause of lost days to US warfighters is due to accidents and musculoskeletal injuries involving the use of their equipment.

Given that most tasks are performed with the hands which require the use of the shoulder, arm, and hand (referred to as the ARM here on), manual ARM strength (MAS) is relevant for most task analyses and is the limiting factor for many. In order to significantly address the injury numbers above requires the ability to accurately predict exposure to risk of injury for tasks involving MAS, preferably before assigning those tasks to workers.



While methods and tools to assess MAS exist and have been widely used for many years, the injury numbers speak for themselves. Clearly, the existing methods and tools currently being used to determine exposure to risk of injury for tasks involving MAS are not accurate enough.

Dr. Jim Potvin (Prof. Emer., McMasters University) questioned the validity of some of the assumptions the current methods make when determining MAS. For example, many widely used methods to determine MAS are based on the strength of individual axes of rotation at each joint of the ARM. This common approach typically represents the ARM using 3 degrees of freedom (DoF) at the shoulder, 1 DoF at the elbow, and 3 DoF at the wrist/forearm. MAS analysis using this approach seeks to identify which of the individual strengths of the ARM joint axes will limit the ability to perform a task, as if identifying the weakest link in a chain. The problem with this approach is that it assumes each of the ARM's axes has its own independent strength even though this is impossible, as many of the ARM's muscles act about multiple joint axes simultaneously.

Potvin and his colleague, Dr. Prof. Nick La Delfa (now a Professor at the University of Ontario Institute of Technology), performed an extensive study that not only confirmed their concerns but also revealed that the **RMS errors associated with the current, widely used methods are greater than 16 lbs**. (*Reference, "Hall et al 2016", Hall, A.D, La Delfa, N.J, Potvin, J.R. Ergonomics software packages do not accurately estimate manual arm strength for ergonomics assessments. Canadian Society of Biomechanics Conference, Hamilton, ON, July 2016.*)

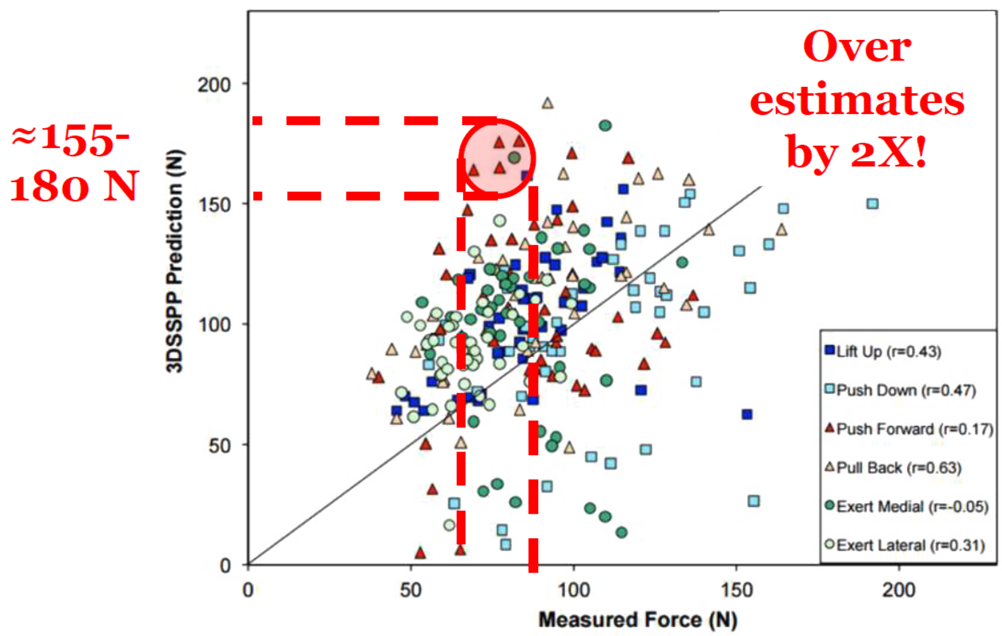


Figure 1

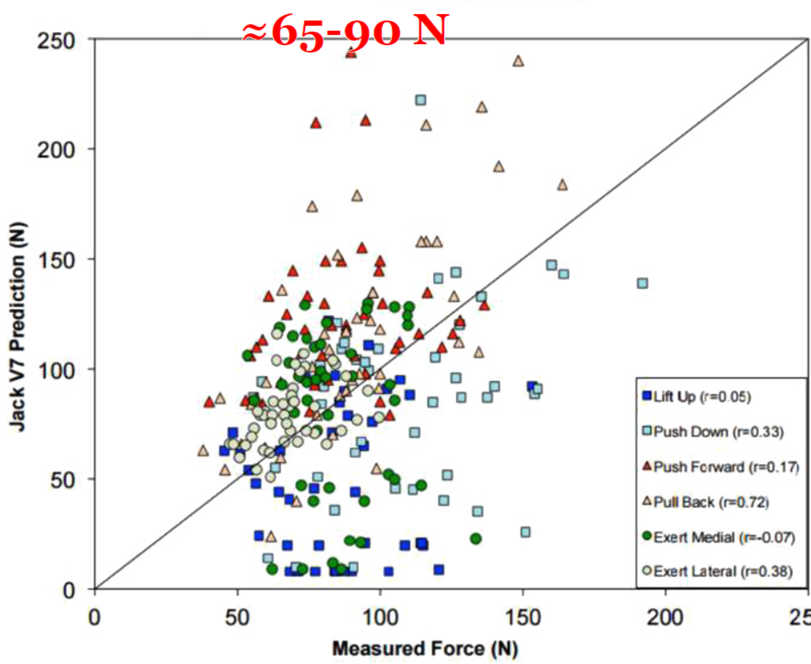


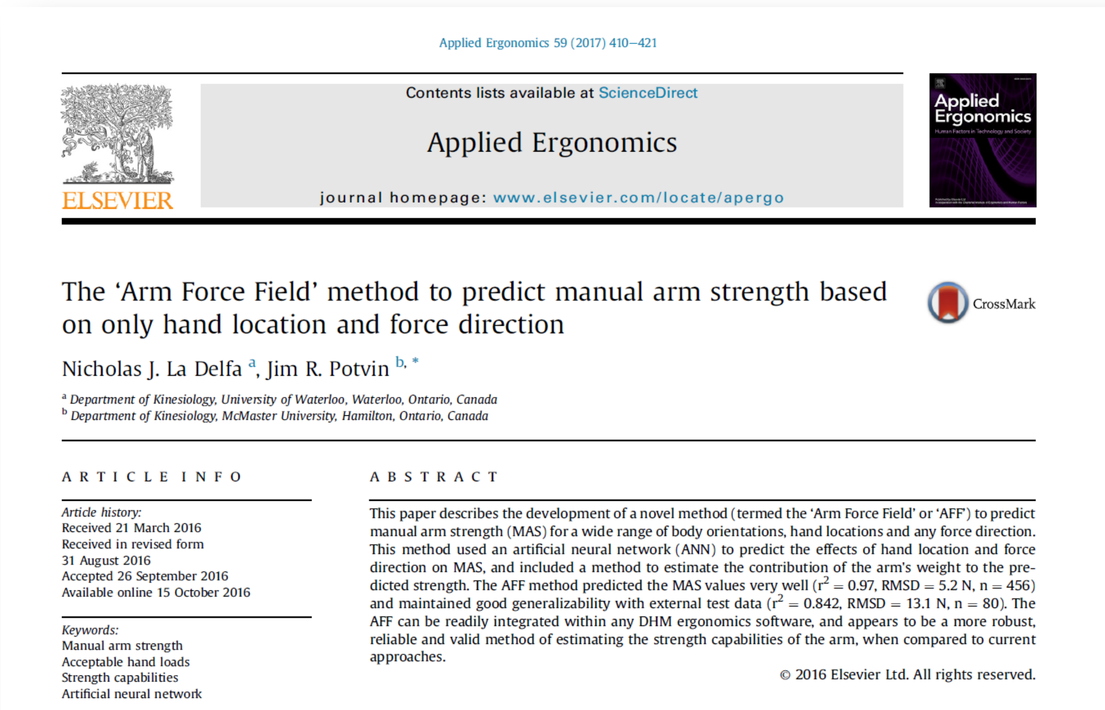
Figure 2

Figures 1 & 2, La Delfa, N. (2011). An evaluation of female arm strength predictions based on hand location, arm posture and force direction. Hamilton, Ontario: M.Sc. Thesis, McMaster University.

This means that existing, commonly used methods can expose workers to significant increases in risk of injury when strength is underestimated, or result in tasks easily done without significant exposure to risk of injury, to be unnecessarily and very expensively redesigned when strength is overestimated.

Potvin also thought that, since engineers and designers really only need to know the maximum acceptable MAS, identifying the limiting joint axis strength of the ARM (as current MAS assessment methods do), is not only inaccurate, it is irrelevant.

With all of this in mind, Potvin decided that it would be better to measure MAS directly at the hand and come up with a method that could accurately predict task strength requirements based only on the hand location and the force direction.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The 'Arm Force Field' method to predict manual arm strength based on only hand location and force direction

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A B S T R A C T

This paper describes the development of a novel method (termed the 'Arm Force Field' or 'AFF') to predict manual arm strength (MAS) for a wide range of body orientations, hand locations and any force direction. This method used an artificial neural network (ANN) to predict the effects of hand location and force direction on MAS, and included a method to estimate the contribution of the arm's weight to the predicted strength. The AFF method predicted the MAS values very well ($r^2 = 0.97$, RMSD = 5.2 N, n = 456) and maintained good generalizability with external test data ($r^2 = 0.842$, RMSD = 13.1 N, n = 80). The AFF can be readily integrated within any DHM ergonomics software, and appears to be a more robust, reliable and valid method of estimating the strength capabilities of the arm, when compared to current approaches.

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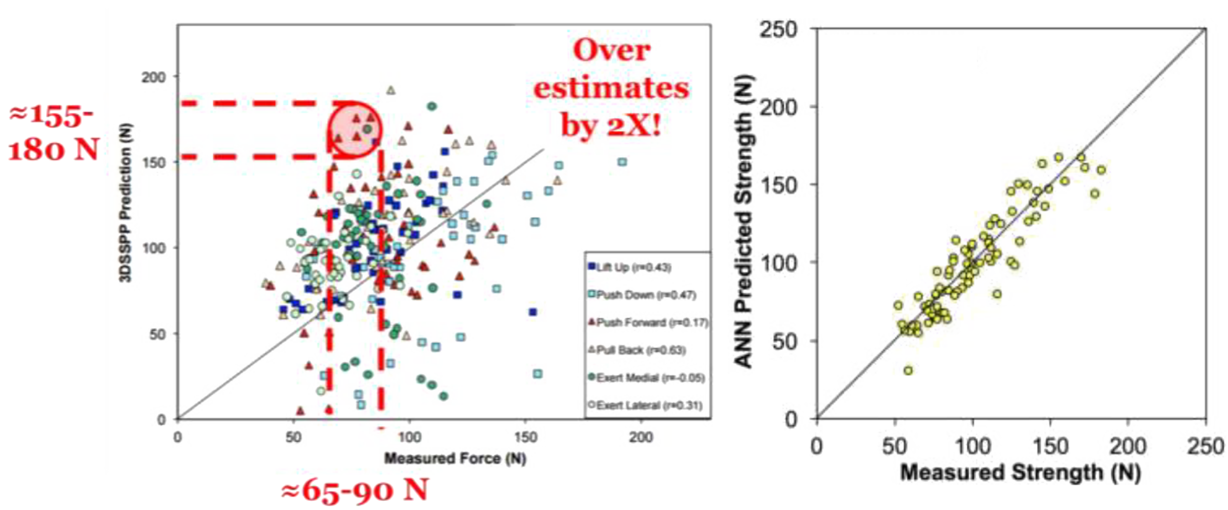
Figure 3

Predicting Exposure to Risk of Injury

Based on over 12 years of research, the Arm Force Field method is the most accurate and extensively validated method of predicting exposure to risk of injury available today. **Available within Santos® Pro and as an add-on to Santos® Lite, the AFF Plug-In** includes:

- Empirical data from 95 healthy, female participants for 36 hand locations and up to 26 force directions where the total n is 536 conditions, 13,660 trials, and approximately 25 subjects per trial.
- An artificial neural network, which has been extensively validated and shown to be



extremely accurate at estimating MAS across a wide variety of conditions, providing an <u>RMS error of only 1.4 lbs. (compared to the 16+ lbs. for the current, widely used methods)</u>.

Figure 4

La Delfa, N.J., & Potvin, J. R. (2017). The "Arm Force Field" method to predict manual arm strength based on only hand location and force direction. Applied Ergonomics, 59, 410-421.

Predicting Exposure to Risk of Injury

The Santos® Arm's Force Field plug-in speaks directly to a significant need for an accurate, validated solution. "There are growing discussions about health care costs, advances with manufacturing in the United States, and whether or not technology really helps individual workers," said Dr. Tim Marler, Chief Research Officer at SantosHuman. "Socially, there's always a need to help reduce injuries and make people's lives better. Technically, there's a growing need for integrated and linked models that help address more complex problems. Release of Santos® Arm's Force Field addresses both of these needs, and it's exciting to move forward in these regards."

"What do you do in your daily life that doesn't involve your hands?" said Steve Beck, President and CEO of SantosHuman. "We now have a module that allows engineers and designers to look specifically at exertions at the hand over a broad range of movements and forces, and obtain a highly accurate and validated means of saying, 'If we're going to ask people to perform a task, this is what that task represents with regards to exposure to risk of injury."