UNDIAGNOSED MOVEMENT DISORDER IN SPEED SKATING: A POSSIBLE FORM OF TASK SPECIFIC DYSTONIA

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This study aimed to investigate the bio-mechanics of a mysterious and undiagnosed movement disorder among expert speed skaters known as skater's cramp. Recent clinical research indicates that the disorder may be a form of task specific dystonia. Using a novel program for analyzing speed skating gait cycles, this study looked at the qualitative kinematic features of the aberrant jerking movement experienced by skaters with skater's cramp. We collected accelerometer data using IMU sensors, and performed a qualitative analysis of multiple normalized gait cycles, focusing on angular velocity around the vertical axis. Results showed skater's cramp was person specific, that it had a clear, consistent asymmetry that was predictable across multiple gait cycles irrespective of speed or intensity of skating. We concluded from this qualitative analysis, that skater's cramp is a form of task specific dystonia.

KEYWORDS: Speedskating, Task-Specific Dystonia

INTRODUCTION: There is an undiagnosed movement disorder in speed skating. The disorder is currently only known by its Dutch name: *zwabbervoet,* or 'wobble-foot' (here to be further referred to as 'skater's cramp'). Skater's cramp is a sudden, uncontrolled twitch-like spasm in a skater's foot that occurs during, or shortly before, the skater places their skate on the ice after a completed stroke. Development of this disorder reduces fine motor control and stability in skilled professional skaters almost certainly spelling the end of their career. The prevalence and pathophysiology of skater's cramp is unknown, with theories ranging from arterial occlusion to compartment syndrome; however, there is little hard evidence to support these claims (Dool, Visser, Koelman, & Koning-Tijssen 2014).
An earlier pilot study conducted in 2014 came to the conclusion that skater's cramp may be a form of task specific dystonia (TSD). TSD is a career-ending movement disorder commonly found in skilled experts ranging from musicians to golfers (Pirio Richardson et al., 2017). There are many factors implicated in TSD, among them, neurocognitive changes in the brain and central nervous system, leading to maladaptive changes to motor engrams that drive complex learned skills (Altenmüller & Jabusch, 2009). A clinical survey of skater's cramp revealed it shares many characteristics of TSD. Both conditions exhibit repetitive consistent jerking, are task-specific, exclusive to skilled experts, have a sudden onset, and persist irrespective of changes in weight or velocity of the movement. In addition to the clinical survey, the pilot study included accelerometer and video recordings. We took these initial kinematic measurements, and performed a new, more expansive analysis. Accelerometer data was filtered through a series of classification algorithms able to differentiate key features of the skating stride consistently, allowing for a reliable and novel gait cycle analysis. The Kinematic analysis supported the hypothesis that skater's cramp may be a form of TSD.

METHODS: *Participants:* The initial pilot study (5), and two newly discovered cases made up a cohort of 7 adult speed skaters (minimum ten years' experience skating at a high level for whom we received informed consent) with a minimum of 6 months suffering from skater's cramp. Skater's performed an assessment of their skating with a fixed program of a total of 5 laps of the

400m ice track, and one steady acceleration. The control group consisted of two experienced speed skaters not suffering from the condition who were measured using the same protocol for the collection of accelerometer data.

IMU's: Participants in the initial study were fitted with portable Inertial Motion Units (IMUs) measuring angular velocity (rad/s), acceleration (m/s^2), and magnetic field strength (mgauss) at a sampling rate of 100 Hz. The new participants used comparable IMUs (Shimmer3 shimmersensing.com), but with a higher sample rate (500Hz). The accelerometers were fixed tightly to the tip of each skaters shoe. The accelerometers were placed on a biaxial (x, y) adjustable platform. An angle protractor helped gauge a rough baseline for yaw- and pitch angle at approximately zero.

Data Processing: A tailor-made program (van der Eb et al., 2017) written in MATLAB 2017a (MathWorks Inc., Natick, MA) was employed for signal processing. Accurate gait-cycles were detected for both the straightaway and corner strides, cut from the moment the skate pushed off the ice (push), and also from the moment the skate was set down after the push (skate-placement). To increase accuracy of gait cycle analysis, gait cycles were normalized in two sections, from push to skate-placement, and from 'skate-placement to 'push'. These gait cycles were fused.

Analysis: The angular velocity (rad/s) around the vertical axis of rotation (z axis) was graphed for normalized gait-cycles for the left and right skate during the straightaway portion of the laps. We graded accelerometer signals qualitatively looking for signs of regularity, consistency in different skating conditions and person specificity. Results from the clinical survey were assessed for the prevalence of characteristics indicative of focal task specific dystonia, including suddenness of onset, task specificity and experience of the participant.

Figure 1: One full gait cycle for a speed skater consists of a push, swing and glide phase. Skate-placement is the precarious moment where skaters must shift their centre of gravity over the alternate skate while placing it on its outside edge.

RESULTS: Gait-cycles from the two affected participants above (Figure 2 and Figure 3) show the maladaptive jerk as a clear, consistent and person-specific asymmetry for the affected skate compared to the unaffected skate. In contrast, healthy skaters exhibit symmetry between right and left skates. Furthermore, the jerk in affected skaters shows a higher magnitude of angular velocity compared to their healthy leg, and compared to healthy participants. Therefore, the jerking movement appears to be person-specific, consistent and predictable across multiple gait cycles irrespective of speed or intensity and asymmetrical (both in magnitude and kinematics) compared to healthy subjects.

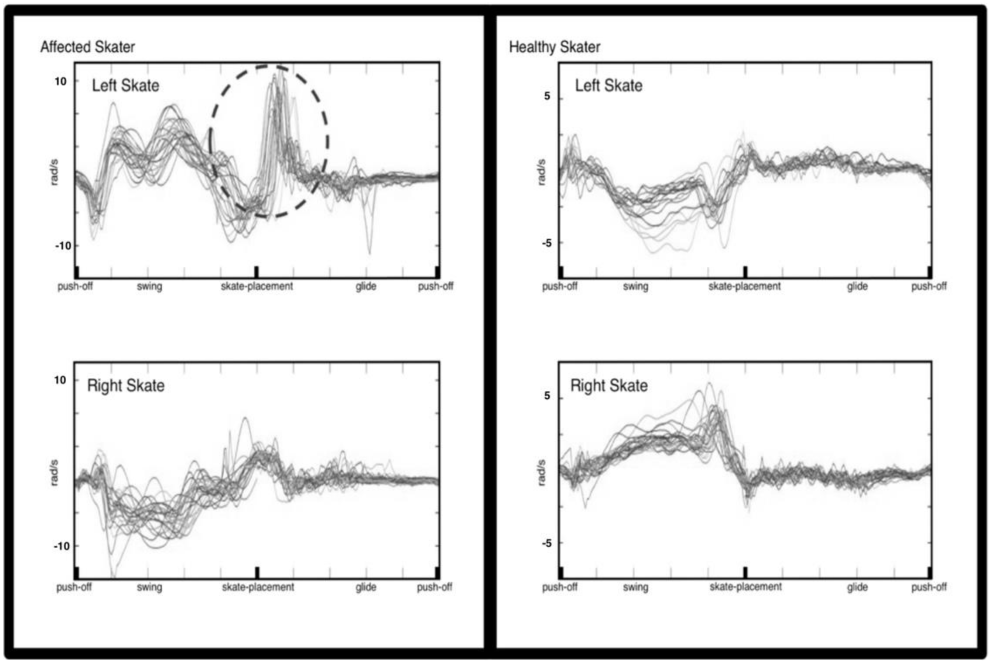

Figure 2: Participant one, angular velocity (rad/s) around the vertical (z axis) for 30 normalized gait cycles are portrayed for an affected and healthy skater. The dystonic skater's cramp (circled) occurs always either directly before, or directly after skate placement. The aberrative jerking motion is regular, persists irrespective of changes in velocity.

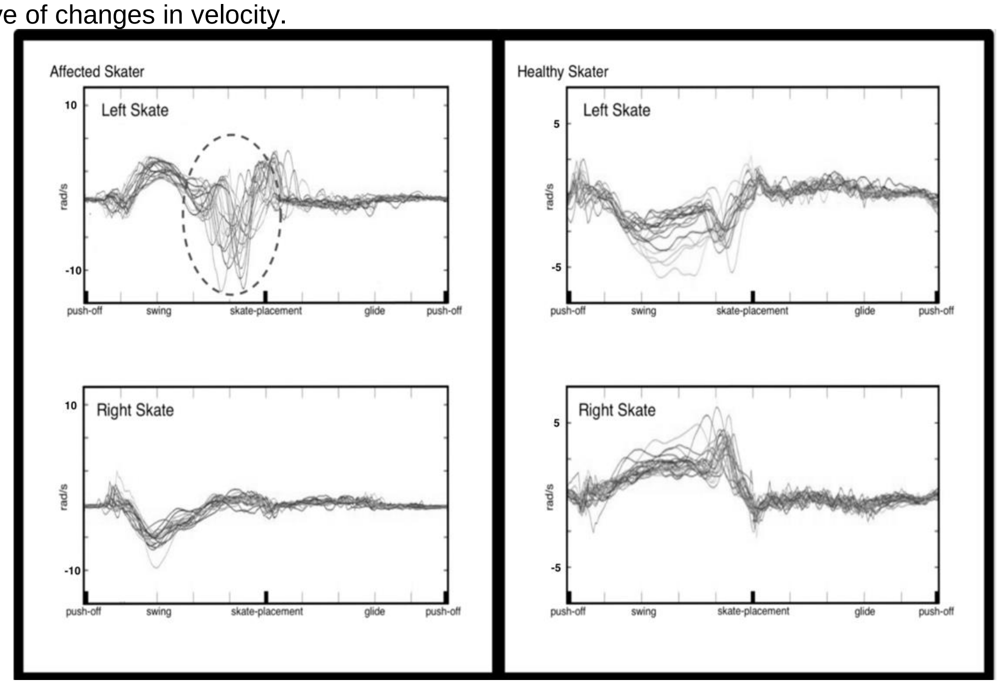

Figure 3: Participant two, looking at the results from another participant, we see a very different pattern of aberration, but the locality of the disorder and its regularity over multiple gait-cycles is apparent. This indicates the disorder is person-specific.

DISCUSSION: *Clinical survey:* The clinical survey indicated that skater's cramp fulfils many of the key criteria of TSD. Participants responded that they all experienced skater's cramp as an involuntary and often unnoticed jerk, furthermore the movement disorder was *task-specific*, meaning affected skaters only reported it in their skating, and not in other skilled abilities.

Additionally all skaters were skilled experts, with skaters averaging over a decade of experience. Finally they all reported a sudden onset, with clinical surveys of skater's cramp suggesting it has an onset period of only a few weeks on average. Occurring in experienced experts, being involuntary, unnoticed, task specific and, arising suddenly are all important indicators of TSD.

Kinematic Analysis: The renewed and more in-depth analysis was thanks to the gait cycle selection algorithm (van der Eb et al., 2017). The gait selection classifier located key consistent events in in the skating gait cycles related to acceleration and angular velocity, allowing for differentiation of the beginning and end of the glide/push phase and the swing phase. Never before has it been possible to consistently and accurately isolate gait-cycles in a speed skater. This allowed for the first qualitative analysis of the variance and regularity of movement patterns across multiple gait-cycles in speed skaters. The kinematics of affected skaters indicated jerking movements that occur consistently irrespective of changes in velocity or intensity of skating. They also seem person specific, so although there is great consistency in the dystonic jerk across gait cycles, everyone's maladaptive movements appeared different. The person and task specificity of the condition, combined with its highly predictable presentation are all key features indicative that skater's cramp may be a form of TSD.

Although further analysis is needed, cursory visual cues show similar variance in the clustered gait cycles. Besides the dystonic jerk, it doesn't seem that affected skaters show lower accuracy or consistency in their stride. Therefore, the disorder appears to be specific to a particular movement (skating), but also to a particular part of the skating movement: skate placement, with the rest of the stride not differing significantly from the controls. This 'focality' in skater's cramp, combined with the consistency of the jerking motion, are common indicators of TSD and further supports the hypothesis that they are related.

Analysis in Development: In future analyses, EMG and pressure sensing will be employed to further investigate the specificity of the deviation across the entire gait cycle. As with these initial kinematic results, we predict only differences in muscle activity and force production during skate placement, and not during the push, swing and glide phase. In addition to EMG and Pressure sensing being added to the analysis, 3 extra accelerometer sensors will be added to the measurement to pave the way for analysis of limb dynamics in a global coordinate system.

To further elaborate on the previous clinical analysis, an agreement has been made with the National Dutch Speed Skating Association (KNSB) to perform a far-reaching survey to provide the first evidence for the prevalence of this movement disorder, and to gain an even deeper understanding of its clinical characteristics.

CONCLUSION: This study demonstrates a new in-depth method of analysing the biomechanics of skater's cramp, an undiagnosed and serious movement disorder affecting expert speeds skaters. Based on an already existing data set from 2014, expanded upon with two new participants, early qualitative analysis indicates the consistency, facility and person-specific distinctiveness of the disorder, supporting the hypothesis that it is a form of task specific dystonia.

REFERENCES:

Altenmüller, E., & Jabusch, H. C. (2009). Focal hand dystonia in musicians: phenomenology, etiology, and psychological trigger factors. *Journal of Hand Therapy*, *22*(2), 144–155. http://doi.org/10.1016/j.jht.2008.11.007

Dool J vd, Visser B, Koelman H, Koning-Tijssen MAJ de. Reactie op 'Een schaatser met een zwabbervoet'. Fysiopraxis. 2014 Mar. (Dutch).

Pirio Richardson, S., Altenmüller, E., Alter, K., Alterman, R. L., Chen, R., Frucht, S., … Hallett, M. (2017). Research Priorities in Limb and Task-Specific Dystonias. *Frontiers in Neurology*, *8*(May). http://doi.org/10.3389/fneur.2017.00170

van der Eb, J., Mossink, H., Kiel, E., Geraets, S., Veeger, D., & Beek, P. J. (2018). *ANALYSIS OF IN COMPETITION SPEED SKATING USING IMU'S*. Paper presented at the 36th Conference of the International Society of Biomechanics in Sports, Auckland.