JOINT ANGLES AND FORCES ON WRIST STRUCTURES DURING VARIATIONS OF YOGA POSES

Ashley L. Hawke, Abby J. Carey, Stephanie L. Carlson-Ballone, Randall L. Jensen

School of Health & Human Performance, Northern Michigan University, Marquette, MI, USA

The current study analysed joint angles of the wrists and forces on the structures in the hands and wrists in a hyperextended position and a neutral position during three different yoga poses. Participants (n = 9) performed three yoga poses (plank, side plank, and upward dog), with their wrists in a hyperextended position (H) and a neutral position (N). Each pose was completed three times for 10 seconds in H and N, for a total of six trials per pose. A two-way Repeated Measures ANOVA found significant differences in both wrist joint angles and GRF between H and N. Due to the suggested path transmission of forces, as well as the increased longitudinal loading that comes with wrist hyperextension, it is recommended that plank, side plank, and upward dog be performed in a neutral wrist position.

KEYWORDS: plank, side plank, upward dog.

INTRODUCTION: The practice of yoga has grown in popularity due to its integration of physical, emotional, spiritual, and mental aspects (Ni, Mooney, Balachandran, Richards, Harriell, & Signorile, 2014; Swain & McGwin, 2016). Benefits of engagement in regular yoga practice include increased muscular strength and endurance, muscular and anaerobic power, flexibility, balance, and coordination (Cowan & Adams, 2005; Ni et al., 2014; Tran, Holly, Lashbrook, & Amsterdam, 2001). Additionally, several studies have investigated the incorporation of yoga as a complementary therapy and have shown that practicing yoga has resulted in attenuation of pain, specifically of the back, knees, neck, and hands (Ni et al., 2014; Swain & McGwin, 2016). When practiced correctly, with a well-educated instructor, yoga is safe for healthy individuals (National Institutes of Health, 2019). However, incorrect technique and instruction, as well as previous injury and excessive effort, have resulted in injury among participants, with injuries commonly occurring to the neck, lower back, knees, shoulder, and wrists. Swain and McGwin (2016) found that injuries of the upper limb (i.e., elbow, lower arm, wrist, upper arm, hand, and fingers) accounted for about 9% of all yoga injuries reported in the United States between 2001 and 2014.

Sun Salutation is a common yoga sequence, consisting of 10 postures, meant to be performed in a single, continuous flow (Omkar, Mour, & Das, 2009). Because of its rigorous sequence, high rate of energy expenditure, and numerous benefits, such as decreased menopausal symptoms and perceived stress, Sun Salutation is often the sequence of choice for practitioners (Chattha, Raghuram, Venkatram, & Hongasandra, 2008; Omkar et al., 2011). Several studies have investigated joint forces and moments during various yoga poses, with much of the focus on the lower extremities (Westwell, Bell, & Ounpuu, 2006). Recently, Omkar et al. (2009) developed a mathematical model of the effects of Sun Salutation on specific joints. However, this model only applies to poses done with a hyperextended wrist, not a neutral position.

Many of the yoga positions completed in a Sun Salutation sequence, such as plank or upward dog, are executed in a hyperextended wrist, with little to no standard guidelines of optimal wrist and hand position (Polovinets, Wolf, & Wollstein, 2018). Repetition of suboptimal loading on a hyperextended wrist may lead to early development of wrist pain and carpal tunnel syndrome, as well as fracture or dislocation of the wrist (Polovinets et al., 2018). Polovinets et al. (2018) investigated the dynamic loading of the wrist during push-ups on both a hyperextended and neutral wrist. The authors concluded that when performing push-ups with a hyperextended wrist, forces travel through the tissue of the wrist and forearm, which are not suitable for force absorption. On the contrary, when push-ups were performed with a neutral wrist, forces were transferred through bone and joint structures rather than tissues, resulting in the recommendation of performing dynamic loading push-ups with a neutral wrist (Polovinets et al., 2018). No recommendations were made by the authors for hand and wrist position during static loading. Therefore, the purpose of the current study was to analyse joint angles of the wrist and forces on the structures in the hands and wrists in a hyperextended and a neutral position during three different yoga poses: plank, side plank, and upward dog.

METHODS: For this study, 5 females and 4 males (n = 9; mean ± SD: age = 24 ± 4 yrs; body mass = 82.1 ± 16.0 kg; height = 175.3 ± 12.4 cm) volunteered. Inclusion criteria required the participant to have familiarity of yoga and have an absence of upper extremity pain or injury in the 6 months prior to involvement in the study. Permission to complete the study was obtained from Northern Michigan University's Institutional Review Board (Approval Number: HS17-882). Prior to testing, participants were asked to report their dominant side by answering the question, "Which hand do you write with?" Next, participants had retroreflective markers placed on the second and fifth metacarpals of their hands (M2 and M5, respectively), as well as the medial and lateral styloid processes of the wrist and the medial and lateral epicondyles of the humerus, for a total of 6 markers on each forearm. Motion capture was recorded using a 10-camera Motion Analysis Corporation (MAC) system (Santa Rosa, CA, USA). Following marker placement, a certified yoga instructor demonstrated how to perform three common yoga poses: plank, side plank, and upward dog and participants were allowed time to familiarize with the poses. Each pose was completed in a hyperextended position (H; with the hand pronated and flat on the ground) and a neutral position (N; with the hand in a fist position, rotated medially, with the knuckles on the ground), with hands centered on two AMTI force platforms (Watertown, MA, USA). During the side plank pose, participants completed the pose bearing weight on their dominant side (i.e., participants' dominant hand was on the force plate). Each pose was held three times for 10 sec in H and N, for a total of 6 trials per pose. One minute of rest was administered between each trial.
The third trial of each pose and variation was used for data analysis. Kinematic and kinetic data were filtered using a low pass, Butterworth filter with a cut-off frequency of 6 Hz (Winter, 1987). Upper limb kinematic and kinetic variables were calculated using a conventional upper extremity model in Visual 3D (v. 4.0, C-Motion, Inc., Germantown, MD, USA). Ground reaction forces (GRF) and wrist flexion during each pose were measured and analysed. GRF were normalized to percentage of participant body weight (BW).
Paired t-tests compared differences in wrist flexion angle and GRF between dominant and non-dominant sides in plank and upward dog. Since no significant differences were found ($p > 0.05$), wrist flexion and GRF during plank and upward dog were averaged across dominant and non-dominant sides. A two-way Repeated Measures ANOVA was used to analyse differences across poses and variations through IBM© SPSS (v. 26, IBM, NY, USA). Bonferroni corrections were used for pairwise comparisons when there were significant Main Effects ($p < 0.05$). Significance level was set at $p < 0.05$ when significant Main Effects were found ($p < 0.05$).

RESULTS: Figure 1 displays wrist flexion angle and GRF differences, between H and N during plank, side plank, and upward dog. Both wrist flexion angles and GRFs were significantly greater in H compared to N ($p < 0.001$, $p < 0.05$, respectively). Additionally, significant differences were observed in GRF between side plank and upward dog ($p < 0.05$). A significant interaction was present for pose and variation in GRF ($p < 0.05$). No significant differences were observed in wrist flexion between poses ($p > 0.05$).

DISCUSSION: The aim of the current study was to analyse forces on the structures in the hands and wrists in a hyperextended position and a neutral position, as well as joint angles of the wrist, during three different yoga poses: plank, side plank, and upward dog. Significant differences were found in joint angles and GRF between H and N in plank, side plank, and upward dog. Additionally, it was found that GRF were significantly larger during side plank compared to upward dog, as well as a significant interaction between GRF and pose.

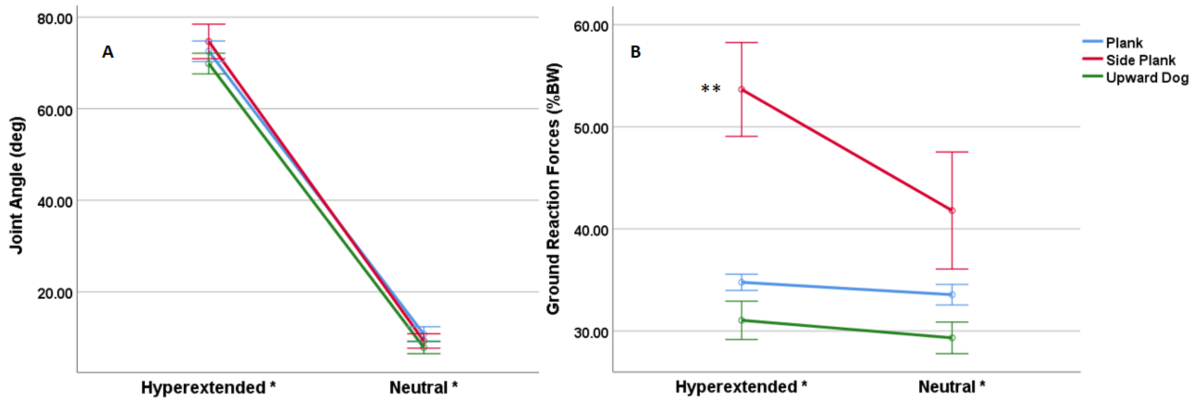

Figure 1. Mean (± SEM) joint angles (A) and GRFs (B) of plank, side plank, and upward dog. Joint angles and GRFs were significantly larger during V1 than V2 (*). Significant differences were observed in GRFs between side plank and upward dog (**).

Average GRFs were significantly greater during H than N in all three yoga poses. This finding is consistent with previous research that has compared the forces in the wrist during push-ups. As previously mentioned, Polovinets et al. (2018) studied dynamic loading of push-ups with a hyperextended wrist and a neutral wrist. The authors concluded that when performing push-ups with a hyperextended wrist, forces travel through the ligamentous structures of the wrist and forearm. Over time, force absorption within the tissues may lead to overuse injuries of the wrist, elbow, and shoulder. However, when push-ups were performed with a neutral wrist, forces were transferred through bone and joint structures. This led the authors to recommend that to reduce the risk of injury, individuals should perform dynamic loading push-ups with a neutral wrist (Polovinets et al., 2018). While no suggestions were made by the authors regarding wrist position during static loading, due to the significant differences in GRF between H and N, the results of the current study suggest similar recommendations of performing plank, side plank, and upward dog with a neutral wrist versus a hyperextended wrist, which also follows workplace recommendations to reduce musculoskeletal disorders at the wrist set forth by Malchaire, Cock, and Rober (1996).

While the travel path of the forces exerted on the wrist were not measured in the current study, previous research has shown that the GRF passes more radially through the wrist in a neutral position and more ulnarly through the wrist in a hyperextended position (Polovinets et al., 2018). As a result, during a hyperextended wrist position, forces may pass through the ligamentous structures of the forearm and upper arm, while forces exerted during a neutral wrist position may pass through the bones and joints of the arm (Polovinets et al., 2018). Over time, repetitive ulnar loading may lead to increased wear and tear of the wrist and potentially lead to injury. Additionally, as forces in the wrist are not dissipated around one sole joint, forces may be transferred to the next joint, resulting in injuries to the elbow and shoulder (Polovinets et al., 2018).

As previously mentioned, a significant interaction between GRF and pose was found, indicating that GRF is significantly affected by pose. As shown in Figure 1B, GRF during side plank decreased from H to N, while GRF during plank and upward dog remained relatively constant between variations. Several anecdotal claims were made by participants during data collection that performing side plank with a neutral wrist was painful and uncomfortable, due to the increased force experienced on the metacarpals. These claims were not made during plank or upward dog. The pain experienced by participants may be due to their weight being supported on one arm versus their weight being dispersed between two arms in the plank and upward dog. Because of the high level of discomfort experienced, participants may have inadvertently or subconsciously shifted their weight towards their feet to relieve some of the force experienced on their metacarpals, which may explain the decrease in GRF from H to N. However, shoulder angles and GRF at the feet were not measured during the current study and should be further investigated.

In the present study, joint angles of the wrist were measured while participants held static positions of each pose. Licassi (2019) conducted a similar study, in which wrist GRF and range of motion (ROM) were measured in plank to downward dog poses in novice and experienced yoga participants. The authors found meaningful differences in sagittal plane wrist ROM (flexion/extension) between experience levels (Licassi, 2019). In the current study, wrist joint angles during plank, side plank, and downward dog were significantly larger in H compared to N, which suggests an increase in longitudinal axis loading on the wrist when the wrist is in a hyperextended (H) position (Licassi, 2019; Malchaire et al., 1996). Additionally, it can be inferred that yoga participants may experience an increased ROM when transitioning through poses with a hyperextended wrist, compared to a neutral wrist. The continuous longitudinal axis loading participants experience when practicing multiple poses and transitions with a hyperextended wrist may result in increased wear and tear of the wrist joint and potentially lead to injury (Licassi, 2019). As a result, it is recommended that plank, side plank, and upward dog be conducted with a neutral wrist to reduce joint angle and in turn, reduce injury risk. Because the ROM of a neutral wrist when transitioning between poses has not been studied, a recommendation of wrist position can only be made for when yoga positions are held statically.

CONCLUSION: Due to the suggested path for transmission of forces, as well as the increased longitudinal loading that comes with wrist hyperextension, it is recommended that plank, side plank, and upward dog be performed in a neutral wrist position, especially for those who experience ligamentous pain or injury, specifically of the wrist.

REFERENCES

Cowen, V. S. & Adams, T. B. (2005). Physical and perceptual benefits of yoga asana practice: Results of a pilot study. *Journal of Bodywork & Movement Therapies, 9*(3), 211-219.

Chattha, R., Raghuram, N., Venkatram, P., & Hognasandra, N. R. (2008). Treating the climacteric symptoms in Indian women with an integrated approach to yoga therapy: A randomized control study. *Journal of the North American Menopause Society, 15*(5), 1-9.

Licassi, I. A. (2019). *A comparison of wrist range of motion and vertical wrist joint forces in plank and downward facing dog positions between novice and experienced yoga participants.* Retrieved from https://search.proquest.com/docview/2300645637?accountid=26724

Malchair, J. B., Cock, N. A., & Robert, A. R. (1996). Prevalences of musculoskeletal disorders at the wrist as a function of angles, forces, repetitiveness and movement velocities. *Scandinavian Journal of Work, Environment, & Health, 22*(3), 176-181.

National Center for Complimentary and Integrative Health; National Institutes of Health. Yoga: What you need to know. https://nccih.nih.gov/health/yoga/introduction.htm. Updated 2019. Accessed November 1, 2019.

Ni, M., Mooney K., Balachandran, A., Richards, L., Harriell, K., & Singnorile, J. F. (2014). Muscle utilization patterns vary by skill levels of the practitioners across specific yoga poses (asanas). *Complementary Therapies in Medicine, 22*(4), 662-669.

Omkar, S. N., Mour, M. & Das, D. (2009). A mathematical model of effects on specific joints during practice of the Sun Salutation – A sequence of yoga postures. *Journal of Bodywork & Movement Therapies, 15*(2), 201-208.

Polovinets, O., Wolf, A., & Wollstein, R. (2018). Force transmission through the wrist during performance of push-ups on a hyperextended and a neutral wrist. *Journal of Hand Therapy, 31*(3), 322-330.

Swain, T. A. & McGwin, G. (2016). Yoga-related injuries in the United States from 2001 to 2014. *Orthopaedic Journal of Sports Medicine, 4*(11), 1-6.

Tran, M. D., Holly, R. G., Lashbrook, J., & Amsterdam, E. A. (2001). Effects of Hatha yoga practice on the health-related aspects of physical fitness. *Preventive Cardiology, 4*(4), 165-170.

Westwell, M., Bell, K., & Ounpuu, S. (2006). Evaluation of lower extremity joint moments experienced during several yoga postures. *Gait & Posture, 24*, S213-S215.

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