J-PAS fleairy Proof of Concept

Reduction in Forces on Lower Back Muscles (Load and Lumbar Torque)

High or even moderate loads applied repetitively to the lumbar spine can increase the risk of low back pain, weaken or damage the vertebrae, and cause intervertebral disc degeneration or herniation. Reducing loading on lumbar tissues during common healthcare workers' activities could help lower the risk of back injury and resultant pain, or benefit other outcomes related to muscle effort and fatigue [1].The J-PAS fleairy has proven to be highly effective in reducing strain during care work. Electromyogram data from the Hyogo Prefectural Social Welfare Foundation's Welfare Town Development Research Institute demonstrates that the exosuit **reduces lower back strain** by approximately **94% when maintaining a half-squat position**, such as during diaper changes, and by **59% when standing**, such as in a toilet setting [2].

JTEKT's Japan team also utilized a motion capture system and a force plate to simulate the load on lumbar joints during a diaper changing operation. Motion capture data was converted into a digital human body model by connecting marker points. Torque at the hip joint was estimated with inverse dynamics using the motion capture and force plate measurements. In **Figure 1**, the orange line shows the subject without J-PAS fleairy's assistance and the blue line with the J-PAS fleairy's assist activated. The addition of the J-PAS fleairy greatly reduced the load on the lumbar joint, visualized in **Figure 2**.

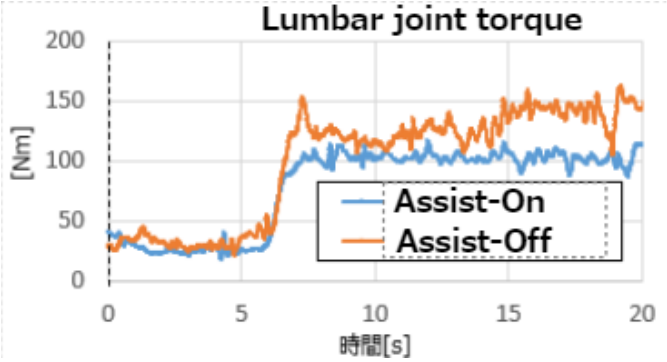

Figure 1: Reduction in load on lumbar joint with J-PAS fleairy (blue) compared to without (orange)

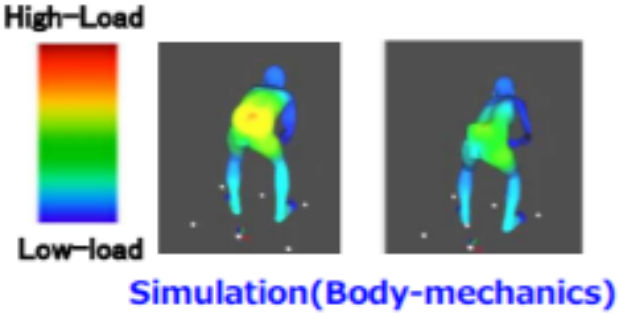

Figure 2: Comparison of load on lower back without J-PAS fleairy (left) to with J-PAS fleairy (right) during diaper changing

Reduction in Fatigue

Fatigue is the state where one cannot sustain a specific exercise level or strength due to either immediate strain or inadequate recovery from repeated physical activity. This exhaustion, whether immediate or residual, stems from a mix of central and peripheral fatigue mechanisms occurring during and after physical exertion [3]. The load measurements done by JTEKT Japan demonstrated the exosuit's ability to reduce joint load in lumbar extensor muscles during leaning positions but reduction of muscle fatigue was unclear. To address this gap, a Clemson University bioengineering team assessed the J-PAS fleairy's effect on reducing lumbar muscle fatigue during forward-leaning tasks. Fatigue was measured by the time to failure during a repetitive lifting/bending motion while holding a 40lb. dumbell. Two adults

performed this task with and without the J-PAS fleairy with a three day rest period in between. This trial was repeated two additional times with a three day rest in between each trial. Results showed a significant increase in time to fatigue while wearing the J-PAS fleairy suit, with an average of 556 seconds compared to 187 seconds without it, indicating a 200% improvement. The study concludes that the J-PAS fleairy effectively reduces muscle fatigue, enhancing endurance and performance in physically demanding tasks, and could improve well-being and productivity in healthcare workers and other professions.

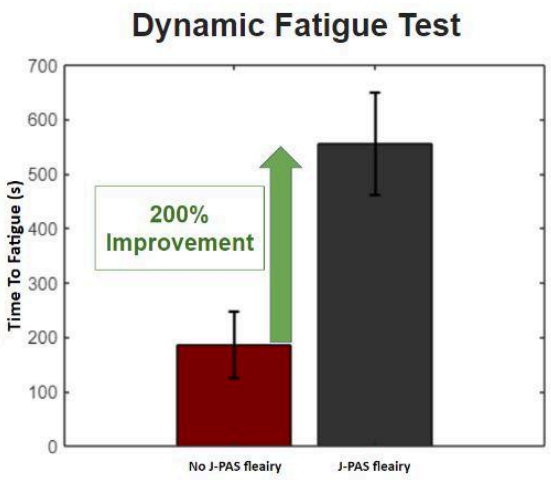

Figure 3: Comparison of Time to Fatigue During Weighted Bending Motion With and Without J-PAS fleairy exosuit

Comparison to Lift Belt

A comparison test was conducted between the percent improvement of a lift belt and the J-PAS fleairy to determine which device more effectively improves time to fatigue during a forward-leaning position, a common posture in patient transfers. Two adult males held a 40 lb dumbbell with a 45° forward lean until failure or discomfort was reported. Each participant completed the test three times for each solution (J-PAS fleairy, lift belt, no equipment) with one day of rest in between each trial. Results showed that the J-PAS fleairy was significantly more effective at increasing time to fatigue with an improvement of 19.5% over the non-equipment average time to fatigue. The lift belt was effective at increasing time to fatigue but at a lower 11.3% improvement. These findings suggest that the J-PAS fleairy may be a more effective solution than a lift belt for reducing low back fatigue and potential injury in nurses performing patient transfers, potentially offering greater protection in clinical settings.

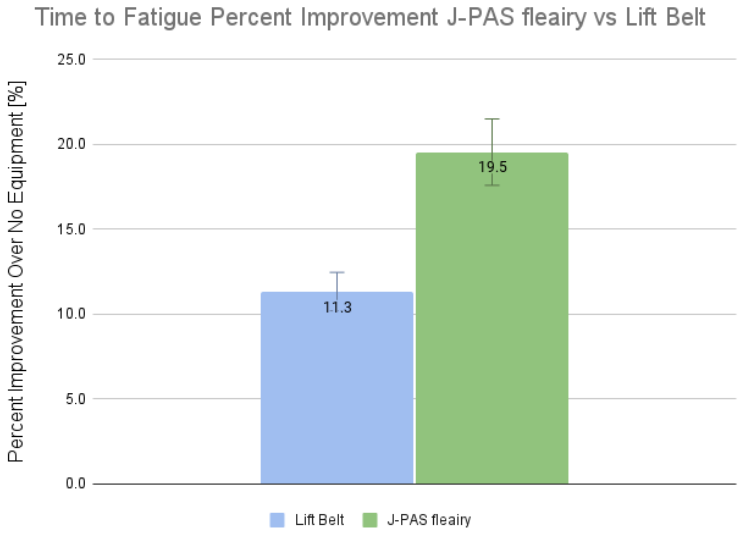

Figure 4: Comparison of Percent Improvement in Time to Fatigue between Lift Belt and J-PAS fleairy when performing 45° static forward lean.

Reduction in Spinal Disc Compression

Around 40% of lower back pain cases result from intervertebral disk degeneration, a condition that is widely linked to mechanical overloading [4,5]. While difficult to measure spinal compression loading in vivo, there are ways to theoretically calculate the reduction using force magnitude and moment arm assumptions [1]. The **reduction of spinal compression** while wearing the J-PAS fleairy and performing a static forward lean with hip flexion and no lumbar flexion at 45° was calculated to be **3.33%**. This is based on the assumption that the subject performing the lift has the anthropometrics of a 50th percentile US male and that there is no additional weight being lifted [6]. The compression load reduction is limited by the moment arm of the exosuit in relation to the intervertebral disks and the force magnitude provided by the exosuit.

Biomechanics Explanation

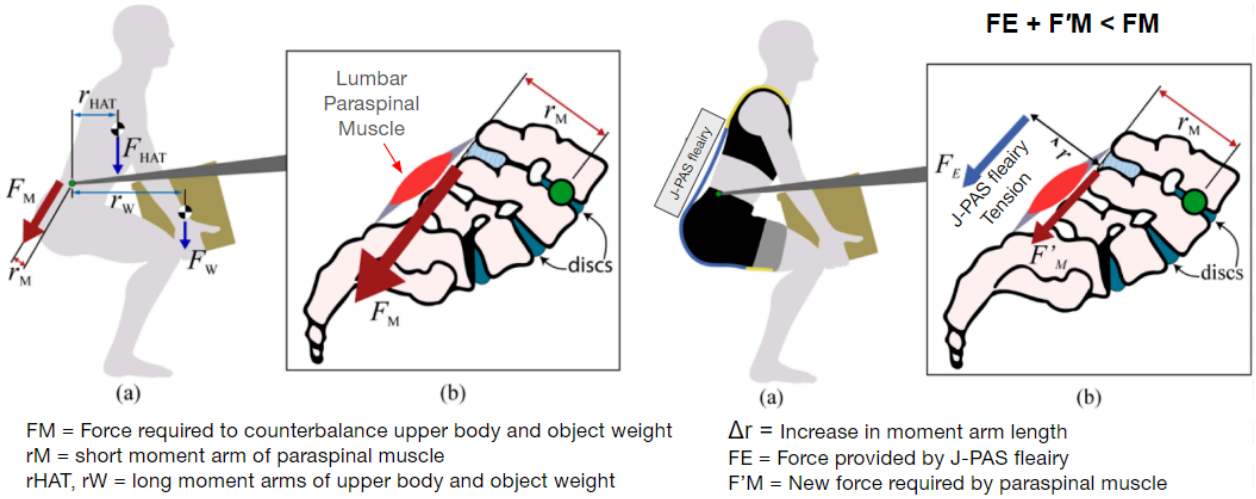

Figure 5: Biomechanical Illustration of the compression load while lifting an object with and without the J-PAS fleairy. Adapted from (Lamers 2018)

At the L5 - S1 intervertebral disc (green dot), there is a clockwise flexion moment created by the weight of the lifted object, and the user's head, arms, and torso. This moment is counterbalanced by a counter clockwise extension moment created by the lumbar paraspinal muscles. Since the moment arm of the muscles is much shorter than the moment arms of the upper body weight, it requires a high magnitude of force to generate the required moment. This force places extra compression force on the lumbar spine and can cause pain and injury. An exosuit like the J-PAS fleairy reduces lumbar tissue loading by creating a longer moment arm and providing a force assist through the tension in the main belt between the backpack and the legs.

References

[1] Lamers, E. P., Yang, A. J., & Zelik, K. E. (2018). Feasibility of a Biomechanically-Assistive Garment to Reduce Low Back Loading During Leaning and Lifting. *IEEE transactions on bio-medical engineering*, *65*(8), 1674–1680. https://doi.org/10.1109/TBME.2017.2761455

[2]「J-PAS fleairy」導入メリット | 介護用アシストスーツJ-PAS fleairy. (2023, November 20). J-PAS Fleairy | J-PAS Fleairy（フレアリー）は、介護専用に設計されたアシストスーツです。介助に必要となる姿勢、動作、そして力をパワフルにアシストし、腰への負荷を大幅に軽減します。. https://active-life.jp/jpasfleairy/merit/

[3] Huygaerts, S., Cos, F., Cohen, D. D., Calleja-González, J., Guitart, M., Blazevich, A. J., & Alcaraz, P. E. (2020). Mechanisms of Hamstring Strain Injury: Interactions between Fatigue, Muscle Activation and Function. Sports (Basel, Switzerland), 8(5), 65. https://doi.org/10.3390/sports8050065

[4] Urits I, Burshtein A, Sharma M, et al. Low back pain, a comprehensive review: pathophysiology, diagnosis, and treatment. *Curr Pain Headache Rep*. 2019;23(3):1-10. doi: 10.1007/s11916-019-0757-1

[5] Adams MA, Roughley PJ. What is intervertebral disc degeneration, and what causes it? *Spine*. 2006;31(18):2151-2161. doi: 10.1097/01.brs.0000231761.73859.2c

[6] de Leva P, “Adjustments to Zatsiorsky-Seluyanov’s segment inertia parameters,” *J. Biomech*, vol. 29, no. 9, pp. 1223–1230, Sep. 1996.