3D Muscle Support Prototype Design That Reduces Load on Upper Extremities and Supports Muscular Strength During Repetitive Arm Movements

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Purpose:

There are many types of industries in which workers carry out tasks that require repetitive arm movements. In particular, fruit farmers perform tasks that involve recurrent raising and lowering of the arms for more than six hours a day on average, which has resulted in approximately 80.5% of the workers in the fruit farming industry developing work-related musculoskeletal disorders in the upper extremities (Kong et al., 2018). To prevent musculoskeletal disorders in any part of the body, it is important to provide support to muscles such as the iliopsoas, obliques, and multifidus, which help maintain a proper posture and serve as sources of strength. Therefore, in this study, we designed prototypes equipped with 3D support that can assist the core muscles and reduce the load on upper extremities of workers who repeatedly use their arms and fail to keep a proper posture during long hours of work.

Keywords: Musculoskeletal disorders, Prototype design, Stability, Moveability, 3D muscle support

Methods:

For the modeling of the 3D support for the core muscles of the abdomen and lower back, the 3D data of the average body shape of Korean men in their 20s from the Size Korea project (2010) were used. The thickness of all modeled supports was set to 0.3 cm, and these supports were 3D printed with thermoplastic polyurethane (TPU). To verify the effectiveness of the 3D support, three types of upper garments were presented as prototypes: one with the 3D support for the abdomen (Proto FW), one with the support for the abdomen and lower back (Proto FW/BW), and one with additional X-shaped backbands attached to support the abdomen and lower back (Proto FW/BW/BBX). In the third prototype, only 85% of the body length was applied to the X-shaped backbands, which were elastic bands. The material of the garments was 100% cotton (plain, thickness: 0.34 mm, density: warp 282, weft 192), and the part of the garment where the 3D support was inserted consisted of two layers of fabric. In the experiment to evaluate these prototypes, nine participants performed the raising and lowering of their arms five times repeatedly, followed by a subjective evaluation.

Results & Conclusion:

For modeling of the support for the abdomen and lower back, a median plane and a transverse plane were created at the location of the navel, and a horizontal plane was created 21.5 cm above

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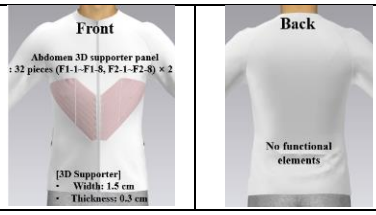
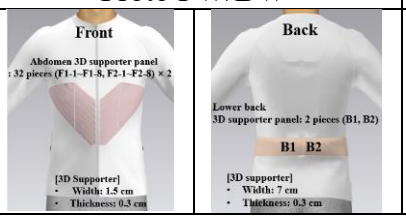
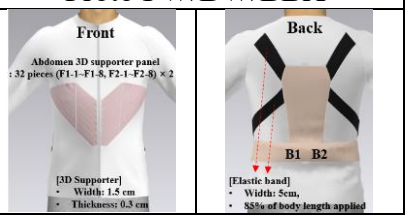
and 5 cm below this location, to divide the body. At the sides, a coronal plane was created in the middle of the waist to divide the body into anterior and posterior sections. First, the support for one side of the abdomen that was vertically bisected by the median plane on the front of the body was modeled in the following order: (1) From the location of the navel, a plane at an angle of 45 degrees was created along the direction of the external oblique, or obliquus externus abdominis; (2) From this plane, seven additional planes above and one below were created with the distance of 1.5 cm between two planes; (3) A dividing line was created at a point 8.5 cm from the median plane, and the support for one side of the abdomen consisting of a total of 16 pieces was modeled. The modeling of the support for the lower back was conducted in the following order: (1) A plane was created 2 cm above and 5 cm below the transverse plane at the location of the navel at the back of the body, (2) Separate modeling was conducted for the left and right sides of the median plane, and the characteristics of the three prototypes to which this was applied are described in Table 1.

Table 1. Three prototypes of 3D muscle support

Proto FW	Proto FW/BW	Proto FW/BW/BBX
		

In the subjective evaluation, Proto FW received 3.0 for body stability, 3.2 for moveability, and 3.4 for clothing pressure. Proto FW/BW received 2.4 for body stability, 2.8 for clothing pressure, and 3.4 points for moveability, which were relatively unsatisfactory results compared to Proto FW. Proto FW/BW/BBX received satisfactory scores of 4.4 for body stability, 3.8 for clothing pressure, and 4.0 for moveability, showing a statistically significant difference in terms of body stability and clothing pressure. Proto FW/BW/BBX is subjectively the most suitable as the 3D muscle support that reduces the load on the upper extremities and supports muscular strength during repetitive arm movements. Objective efficiency verification will be further conducted through muscle activity evaluation using compression garments for each section of the upper extremities.

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