INTRODUCTION

The focus of product development is shifting from the product to the person using the product. It is now essential to consider both the product and the human body at the same time while designing and analyzing any product that requires close interaction with the human body during usage. In order to analyze human motion when human uses a product, it is effective to use motion capture system. But in design stage which doesn’t have a prototype or a real product, it is impossible to use motion capture system. In this case, a method which predicts human posture as using inverse kinematics and optimization, and evaluates a product through simulation. In design stage, the method which creates a human posture is different depending on characteristic and object. Generally an objective function is defined according to an assumption which is human set the most comfort posture. But the product which has a special object, like fitness equipment, it needs to add a constraint to apply the object in posture creation stage. This paper suggests a method creating a human posture with satisfying an additional constraint when human uses incline chest press machine which is one of resistance training machines.

METHODS

In order to predict human posture in design stage and apply the result to a product, the information of the product designed on SolidWorks which is a commercial CAD system is converted to the information which can use on AnyBody which is a musculoskeletal analysis software. And some reference nodes are added for defining the interaction between product and human model.

The constraint which makes the reference node defined on CAD model coincides with end-effector of human model is created in order that human get a posture according the object. For creating the posture which is gotten when human exercise with incline press machine, the interaction between human model and product is defined at hands, foots, pelvis and thorax. The objective function to predict human posture is human body comfort evaluation model used by Marler [1], anyway this research make end-effector coincide with CAD model not only position but also orientation in numerical formula (2).

Objective function:

\[ f_{\text{discomfort}} = \sum_{i=1}^{n} w_i (q_i - q_i^Y)^2 \]  (1)

End-effector position and orientation constraint:

\[ \| X(q) - T_{T_{\text{target}}} \| \leq \varepsilon \]  (2)

Range of each joint angle:

\[ q_i^L \leq q_i \leq q_i^U \]  (i = 1, ..., n)  (3)

In case of general products, human postures can be predicted by optimization using the discomfort function. But in case of products have special purpose; e.g. resistance training machines; postures of human model should consider the purpose of products. In this study, we gave additional constraints between the human model and the product when generating human posture which satisfied the purpose of the product. A trend that the position of the elbow joint is placed on the virtual plane that formed with a shoulder joint and a handle of machine can be found when people using incline chest press machine. The reason for this is
counterbalancing moments generated by weights by sustaining handles of incline press machine by lower arms vertically as possible as human can. To consider this trend when generating human postures, we added end-effectors on each elbow joint of human model and gave soft constraints between end-effectors and virtual planes in AnyBody. By adding additional constraints and using optimization method to minimize $f_{\text{discomfort}}$, we can get the posture of the human model performed an incline chest press motion like Figure 1.

**Figure 1**: Posture of the human model in Anybody satisfied additional constraints on elbow joints (a) initial posture (b) final posture

**RESULTS AND DISCUSSION**

To validate posture of human model considering additional constraints on elbow joints, we compare the simulated human posture with data driven human posture that captured motion of human performed exercise using incline chest press machine. Figure 2 shows compared results about joint angles of glenohumeral joint and elbow joint of a simulated posture and a motion capture data driven posture. Patterns of joint angles of simulated posture are similar to those of joint angles of motion capture driven posture.

**Figure 2**: Compared result of simulated joint angles (blue lines) with motion capture driven motion (red lines), (a) glenohumeral flexion (b) glenohumeral external rotation (c) glenohumeral abduction (d) elbow flexion

**CONCLUSIONS**

In this paper, design information of incline chest press machine acquired from CAD system. And musculoskeletal simulation has performed with combined information of product with musculoskeletal human model to generate human posture. And validate results of new algorithm by comparing with experimental results by producing real machine. If the design or structure of training machine that constrain the human posture has changed, the algorithm assumed in this paper that constrains human posture may change. There are many kinds of algorithms to predict a human motion, however one of those algorithms doesn't guarantee that the algorithm can predict every motions successively. If an algorithm that predicting human postures based on acquired motion capture data when we design a new training machine or equipment is developed, human posture can be predicted even if design parameters of that machine have changed, so design of product also can be optimized to maximize its special purpose.

**REFERENCES**

3. SolidWorks, Dassault Systèmes SolidWorks Corp

**ACKNOWLEDGEMENTS**

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2011-0001147).