JESK J Ergon Soc Korea 2015; 34(5): 437-445
http://dx.doi.org/10.5143/JESK.2015.34.5.437
http://jesk.or.kr eISSN:2093-8462

Trends of Intellectual Property on Musculoskeletal Disorder, Motion Capture Technology and Ergonomics

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Received : August 13, 2015
Revised : August 20, 2015
Accepted : August 26, 2015

Objective: The aims of this study are to investigate the trends of intellectual property in order to identify the ergonomic approaches on musculoskeletal disorders, harmful factors of musculoskeletal disorders, and to find the potential applicability of motion capture technology.

Background: Ergonomic posture assessment tools often showed interrater variance, though the usage is easy and practical in industrial fields. Moreover new technologies such as motion capture showed the potential applicability in posture assessment. So ergonomists and practitioners became interested in the intellectual properties on musculoskeletal disorder and motion capture technology.

Method: Intellectual properties were collected with the combination of keywords such as ergonomic, musculoskeletal disorder, and motion capture using the KIPRIS (Korea Intellectual Property Rights Information Service). Collected intellectual properties were classified into ergonomic area and non-ergonomic area, except unexamined intellectual properties. This study investigated the trend of application of intellectual properties and the probability of using motion capture technology.

Results: Few intellectual properties with ergonomic approach on musculoskeletal disorders were founded, despite many products for rehabilitation and sports. One hundred twenty five patents in 1105 patents on musculoskeletal disorders and 138 patents in 1908 patents on motion capture technology were classified into the patents that ergonomic approach can be applied. The patents related to ergonomics area are rapidly increasing after 2010, and there are good opportunities for ergonomists to apply the patents.

Conclusion: This study found opportunities on novel methodology in detecting the harmful factors of musculoskeletal disorders, and that the motion capture technology is applicable in ergonomic posture assessment.

Application: The results of this study can help ergonomists prepare the ergonomic patents, and can show the potential use of motion capture technology in detecting the harmful posture of musculoskeletal disorders.

Keywords: Musculoskeletal disorder, Motion capture, Intellectual property

1. Introduction

The recognition level of businesses and workers on the prevention of musculoskeletal disorders has improved, due to the enactment of musculoskeletal disorder-related legislation, and the legislation makes the investigation on harmful factors of musculoskeletal disorders be conducted to prevent musculoskeletal disorders in

industrial sites (KOSHA, 2012). When additional precision assessment is judged necessary, as a result of the investigation, additional implementation of the following analysis methods is recommended (Karhu et al., 1977; McAtamney and Corlett, 1993; Hignett and McAtamney, 2000; Moore and Garg, 1995; American Conference of Governmental Industrial Hygienists, 2002): OWAS (Ovako Working Posture Analysis System), RULA (Rapid Upper Limb Assessment) or REBA (Rapid Entire Body Assessment), which are ergonomic posture analysis tools, and JSI (Job Strain Index) and ACGIH's HAL (ACGIH's Hand Activity Level Threshold Limit Values Method), which evaluate the specific human body parts.

Although, ergonomic working posture analysis has such merits as no influence on work, simple use and small cost (Genaidy et al., 1994), there is a possibility that raters can assess one working posture differently in the ergonomic working posture analysis process by rater's observing workers (Burt and Punnett, 1999). Besides, raters may classify working posture with wrong angles, as body joints' angles are segmented (Lowe, 2004), or there is a huge trend that joint angle classification does not match among raters (Bao, 2009).

Active research is carried out on the motion capture technology recently, and it is a technology that can reduce errors among raters by quantitatively measuring body motions. Motion capture can be classified into a mechanical mode, an optical mode and a sensor mode using MEMS (Micro Mechanical System). Since the latter part of the 1990s, the motion capture technology has been applied to body motion measurement to enhance the reality sense of virtual reality (Foxlin, 1996), gait analysis and rehabilitation of rheumatology patients (Sutherland, 2002; Ehara et al., 1997). The motion capture technology is recently utilized in various fields including sports and robotics (Ahmad, 2013). By using the motion capture technology, constant monitoring of working postures at automobile assembly line is possible (Ferguson et al., 2011), or the technology can help correct workers' postures by letting them recognize improper working posture in real time (Vignais et al., 2013). Kim & Nussbaum (2013) showed body motion assessment through motion capture can be highly used for ergonomic working posture analysis, although errors may occur to worker's posture measurement, according to motion capture mode.

This study aims to identify ergonomic approach direction and relevant technology development trends to prevent musculoskeletal disorders through patents having the keywords of musculoskeletal disorders and harmful factors of musculoskeletal disorders, and to check motion capture technology's use possibility for quantitative ergonomic posture analysis.

2. Method

This study used KIPRIS (Korea Intellectual Property Rights Information Service), the intellectual property right information database, to grasp musculoskeletal disorders and motion capture technology trends (KIPRIS Home Page, 2015). Through KIPRIS, one can not only carry out general search using various keywords, but perform specified search using logical operator (*, +, !, ^) and syntax operator (" "). Also, search using 23 various search items in total, such as IPC Classification, publication number, publication date and applicant, in addition to the invention's name, is possible.

Intellectual property right is classified into patent and utility model, according to right, and this study carried out research targeting only patents. This study conducted free words search on full text of patents to identify relations among musculoskeletal disorders, harmful factors of musculoskeletal disorders and ergonomics, and on posture assessment technology trends using motion capture. This study checked whether ergonomic approach was conducted on "musculoskeletal disorders*ergonomics", as well as musculoskeletal disorders, in the patents related to musculoskeletal disorders. This study also examined technology trends to quantify the harmful factors of musculoskeletal disorder investigation, and posture assessment-related patents using motion capture.

This study excluded the patents, of which patent rights perished, application was cancelled, or given up, due to some situation of

applicants. This study analyzed only the patents, of which status of registration was decided through patent examination process in an effort to check the lacking parts of patents that did not pass patent examination and patent rejection ratio together by ascertaining the rejected patents from patent examination process. Since the free words search results of patents are the results on the full text of patent specifications, the fields of machine, electronics, IT and medical service with small relevance with ergonomics were included as well, although the search words presented by this study were included. Consequently, the patents related to equipment, facility and robot for production were classified into machine patents, software and hardware patents for computerized data processing into electronics/computer patents, the patents related to musculoskeletal disorders treatment methods and treatment compositions patents into medical patents. In this manner, a process excluding the patents having just a little relevance with ergonomics was carried out.

3. Results

3.1 Statistical classification

Table 1 shows the patent search results by keyword. Because the search results of ("musculoskeletal disorders")*("ergonomics") are the search results of the patents including "ergonomics" among the search results of musculoskeletal disorders, they are the patents duplicately searched with the search results of "musculoskeletal disorders". 832 patents on musculoskeletal disorders out of 1,528 patents in total were registered, and took up 54.4% of the total. The patents on ("musculoskeletal disorders")*("ergonomics") took up 35.9%, harmful factors of musculoskeletal disorders 21.5%, and motion capture 38.2% in patent registration. This study classified ergonomic field and non-ergonomic field targeting the registered (granted) and rejected patents except unexamined patents in Table 1.

Table 1. Search results of patents for each keyword

Status	Number of patents for each keyword			
	"Musculoskeletal disorder"	("Musculoskeletal disorder") *("ergonomics")	"Harmful factor of musculoskeletal disorder"	"Motion capture"
Applications	1528	92	93	1908
Granted	832	33	20	729
Rejected	273	17	27	267
Unexamined	423	42	46	912

Table 2 summarizes the patents related to ergonomics among the examination-completed patents. 423 patents, of which examination was not carried out, among 1,528 patents searched with the keyword of musculoskeletal disorders, were excluded, and the patents related to ergonomics out of 1,105 patents were summarized as 125 patents. The patents concerned with ergonomics were mainly on posture correction devices or exercise equipment, shoe insoles and functional clothes. In the non-ergonomic field, there were electric tools, machine/facility and medical service-related compositions manufacturing patents. Of the patents searched with ("musculoskeletal disorders")*("ergonomics"), patents in the ergonomic field were 18, and patents on functional clothes supplementing muscular strength or posture took up most of the registered patents. The patents searched with "harmful factors of musculoskeletal disorders" were mostly related to compositions or composition methods, except one manual tool patent. Patents concerned with motion capture were mostly found in computer/IT field. The patents in the ergonomics field out of patents related to motion capture were 138 patents, and they mainly dealt with system constitution and operation methodology

for human motion analysis including sports field.

As for average period from the application for ergonomics-related patents and till acquiring the patent rights, it was 692.4 days for musculoskeletal disorders-related patents, 620.7 days for ("musculoskeletal disorders")*("ergonomics"), 329 days for harmful factors of musculoskeletal disorders, and 799.1 days for motion capture (Table 2). Among the patents extracted as musculoskeletal disorders, 65.6% of the applied ergonomics-related patents were registered as patents through patent examination. The patents related to ("musculoskeletal disorders")*("ergonomics"), in which musculoskeletal disorders and ergonomics are included in the applied patent's full text together were 61.1%. Concerning the patents related to harmful factors of musculoskeletal disorders, only one patent was registered, after application.

Table 3 shows the numbers of patent application and registration in the non-ergonomics field including machine/manufacturing and medical service/drugs among the patents extracted in this study. Among the patents extracted as musculoskeletal disorders, 75.3% were registered as patents, and it took 816.4 days until patent registration. 74.0% of the patents extracted as motion capture were registered as patents, after 919.2 days from application. Patents in the non-ergonomics field were applied from the early 2000s, and the period required for patent examination was long.

Table 2. Search results of patents related to ergonomics

Status	Number of patents for each keyword			
	"Musculoskeletal disorder"	("Musculoskeletal disorder") *("ergonomics")	"Harmful factor of musculoskeletal disorder"	"Motion capture"
Applications	125	18	1	138
Granted	82 (65.6%)	11 (61.1%)	1 (100%)	94 (68.1%)
Rejected	43 (34.4%)	7 (38.9%)	0 (0%)	44 (31.9%)
Period until registration (days)	592.4	620.7	329	799.1

Table 3. Search results of patents related to non-ergonomics

Status	Number of patents for each keyword			
	"Musculoskeletal disorder"	("Musculoskeletal disorder") *("ergonomics")	"Harmful factor of musculoskeletal disorder"	"Motion capture"
Applications	980	32	19	858
Granted	750 (75.3%)	22 (68.8%)	5 (26.3%)	635 (74.0%)
Rejected	230 (24.7%)	10 (31.2%)	14 (73.7%)	223 (26.0%)
Period until registration (days)	816.4	1055.6	78.4	919.2

3.2 Trends of patent application

Figure 1 and Table 4 summarize the yearly registration trend of patents related to ergonomics. The number of patents related to ergonomics temporarily decreased in 2008, and then showed a steady increasing trend based on 2010. Considering that the

collected data was about the patents registered up to July 2015, the patents related to motion capture showed a hugely increasing trend in 2015 than 2014, compared to the patents related to musculoskeletal disorders. As for the patents related to motion capture, the optical mode motion capture-related patents were mainly registered before 2013, and the patents related to motion capture using MEMS sensors began to be registered from 2014. Regarding the patents related to motion capture, the patents to shape and analyze human body motions, irrelevant of motion capture modes, took up most. Namely, many patents related to workers and in the sports field including workers and golf, and gesture interface field for augmented reality were registered.

Forty four patents having keywords of musculoskeletal disorders and motion capture were applied for before 2005, and 17 among those were registered as patents. That is, 38.6% among the applied patents passed patent examination. However, 72.6% of patent registration ratio was shown, since 159 patents among 219 applied patents were registered after 2006. Therefore, not only patent application number, but patent registration ratio passing patent examination goes higher, compared to before 2005.

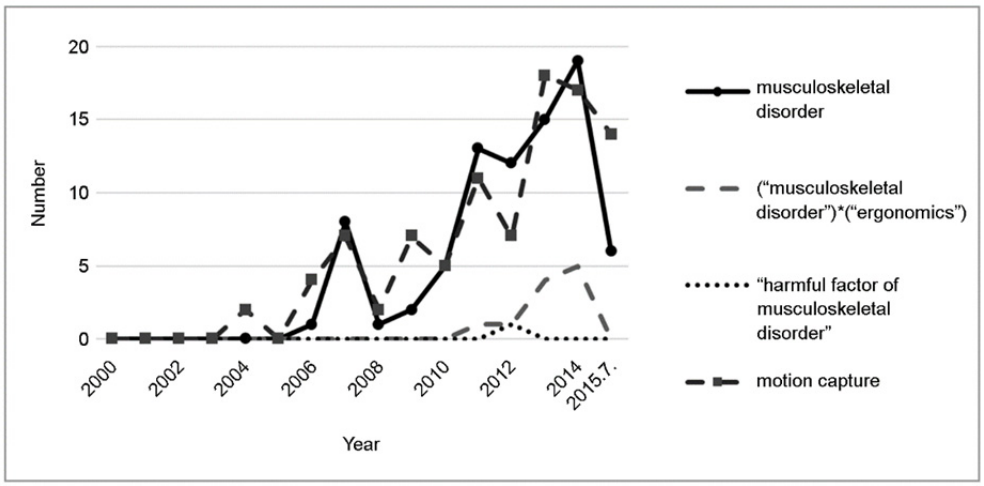

Figure 1. Yearly trend of patent registration

Table 4. Number of patent registration for recent 15 years

Year	Keywords							
	"Musculoskeletal disorder"		("Musculoskeletal disorder") *("ergonomics")		"Harmful factor of musculoskeletal disorder"		"Motion capture"	
	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**
2000	0	1 (0 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	0	5 (2 / 3)
2001	0	1 (0 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	0	5 (2 / 3)
2002	0	2 (1 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	0	4 (1 / 3)
2003	0	2 (1 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	0	6 (0 / 6)
2004	0	1 (0 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	2	5 (2 / 3)
2005	0	5 (2 / 3)	0	1 (0 / 1)	0	0 (0 / 0)	0	7 (6 / 1)

Table 4. Number of patent registration for recent 15 years (Continued)

Year	Keywords							
	"Musculoskeletal disorder"		("Musculoskeletal disorder") *("ergonomics")		"Harmful factor of musculoskeletal disorder"		"Motion capture"	
	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**	Grant.*	App. (Grant./Rej.)**
2006	1	5 (4 / 1)	0	0 (0 / 0)	0	0 (0 / 0)	4	5 (4 / 1)
2007	8	5 (3 / 2)	0	0 (0 / 0)	0	0 (0 / 0)	7	11 (8 / 3)
2008	1	12 (8 / 4)	0	3 (0 / 3)	0	0 (0 / 0)	2	12 (11 / 1)
2009	2	11 (5 / 6)	0	0 (0 / 0)	0	0 (0 / 0)	7	12 (7 / 5)
2010	5	21 (15 / 6)	0	3 (2 / 1)	0	0 (0 / 0)	5	13 (9 / 4)
2011	13	18 (11 / 7)	1	5 (4 / 1)	0	1 (1 / 0)	11	11 (10 / 1)
2012	12	25 (19 / 6)	1	6 (5 / 1)	1	0 (0 / 0)	7	19 (16 / 3)
2013	15	11 (8 / 3)	4	0 (0 / 0)	0	0 (0 / 0)	18	19 (12 / 7)
2014	19	4 (4 / 0)	5	0 (0 / 0)	0	0 (0 / 0)	17	3 (3 / 0)
2015	6	1 (1 / 0)	0	0 (0 / 0)	0	0 (0 / 0)	14	1 (1 / 0)
Total	82	125 (82 / 43)	11	18 (11 / 7)	1	1 (1 / 0)	94	138 (94 / 44)

*: Yearly granted patents
**: Yearly applied patents and (Grant./Rej.) stands for the (Granted/Rejected)

4. Discussion and Conclusion

Many ergonomics-related patents were registered after 2005, in view of the patents registration trend. However, the period did not match between the increase of interest in musculoskeletal disorders and the investigation on harmful factors of musculoskeletal disorders and the legislation enactment on musculoskeletal disorders and on the investigation on harmful factors of musculoskeletal disorders through the rules on industrial safety standards in 2003. The reason is that patent examination period took from three months to five years from patent application to patent registration. In this regard, checking patent application time point is more appropriate to check the current technology trend, although patent registration time point is also important, in order to examine technology development trend through patents. Therefore, the related patents having the keyword of musculoskeletal disorders began to be applied through the enactment of legislation on musculoskeletal disorders and the investigation on harmful factors of musculoskeletal disorders in 2003, and they began to be registered as patents after 2005.

The patents having musculoskeletal disorders as keyword that were applied between 2003 and 2005 were registered as patents between 2006 and 2007. As for the patents applied in 2005, the patents related to body exercise equipment were mainly registered, and therefore, the patents to prevent musculoskeletal disorders or to use for rehabilitation were registered. However, recognition on musculoskeletal disorders or investigation on the harmful factors of musculoskeletal disorders was low in the motion capture field those days, and just some patents on human body motion recognition methods were registered. Namely, patents in the computer field like video data processing were mainly registered.

The patents related to musculoskeletal disorders that were applied for between 2006 and 2010 emphasized biomechanical aspect

more than previous period. Also, they proposed methodology to carry out collection and analysis of body motion data, and the patents applied to the products such as shoe soles and insoles, chairs for work and worktables and rehabilitation exercise equipment began to be applied for. The patents in the motion capture field that combined biomechanical analysis began to be applied for, beyond just collecting body motions. Through data analysis results acquired through motion capture, the patents applied to rehabilitation and walking training started to be applied for, and also began to be expanded into sports field including golf.

As for the patents related to musculoskeletal disorders registered as patents, after being applied for from 2011 till recent time, the patents related to the products that can help the prevention of musculoskeletal disorders increased. The patents related to functional chairs and clothes mainly helping posture correction rose, and also the patents related to posture correction using bio feedback in rehabilitation through body motion and rehabilitation training devices or systems were applied for. In the motion capture field, sports field was expanded enormously, and the patents in the baseball and horse riding fields were applied for. A feature of the application for the patents related to motion capture after 2011 is that such patents increased, as motion capture equipment using MEMS sensors was developed. The patents related to motion capture before 2010 were mainly optical mode motion capture, and thus, patents for marker tracking method and processing method were applied for. However, patents using motion sensors like acceleration sensors and inertia sensors increased, after 2011.

This study examined patent trends in the ergonomic posture assessment field for musculoskeletal disorders and the investigation on harmful factors of musculoskeletal disorders and motion capture field in order to combine the motion capture mode with such ergonomic posture assessment. Although, musculoskeletal disorders and the investigation on harmful factors of musculoskeletal disorders are closely related to the ergonomic field, there were many differences between the extracted patents approachable in the ergonomics field, after extracting patents using musculoskeletal disorders as a single keyword, and the patents containing the keyword of ergonomics in the full text of patent specifications. Such a result is considered to reflect that patent application in the ergonomics field is small among the registered patents until now.

When ergonomics was simply used as a keyword, registered patents were over 7,900; over 300 such patents have been registered each year since 2007, and over 800 patents were registered in 2014. Given that there are various industrial fields to which ergonomics field can be applied, the participation of ergonomics field in the musculoskeletal field can be viewed as starting stage at present. In this regard the fields of musculoskeletal disorders and harmful factors of musculoskeletal disorders mean that the area, where patents from the ergonomic perspective can be applied for, is wide.

This study used an ergonomic posture assessment method, of which cost is small, and that can be used simply, as a method to check the harmful factors of musculoskeletal disorders. However, as revealed in the studies of Burt and Punnett (1999) and Bao (2009), errors can occur between raters, which may affect the judgment of precise posture.

Patents using motion capture mode are recently applied for and registered in Korea, and he application areas are expanding. Not only patents related to methodology measuring and processing body motions precisely, but those in the sports fields including golf and horse riding are the most actively applied in terms of Korea's motion capture-related patents. Regarding the patents related to musculoskeletal disorders, the patent using optical mode motion capture was applied for first-ever in 2007, and was registered in 2009. The patent using MEMS sensors has yet to be registered. Because a patent applied for needs to apply for early publication or is published after 18 months, it is impossible to check all the patents currently applied for. Therefore, the patents on posture analysis using MEMS sensors could not be checked.

This study conducted an analysis to use or acquire related patents in the ergonomics field through patents related to musculoskeletal disorders and the harmful factors of musculoskeletal disorders. As for the patents registered thus far, the patents,

which can be used for musculoskeletal disorders and the investigation on harmful factors of musculoskeletal disorders, were insufficient. The ratio registered as patents by passing patent examination in the ergonomics field including musculoskeletal disorders was lower than the non-ergonomics field (Tables 2 and 3). The reason is that the patents applied for in the ergonomics field were product-related patents, and therefore, it was insufficient to utilize existing theory, or present clear grounds. For example, although patents on posture correction systems to prevent musculoskeletal diseases have been applied for since 2009, they have been rejected in the patent examination process. Even though, precise reasons of rejection in patent examination were not confirmed, it is conjectured that novelty section was not met in the patent requirements under Article 29 of the Patent Act. As for novelty, patents are not awarded to inventions that were announced, to openly implemented inventions or inventions published on publications domestically or internationally. The methodology of a patent applied for to acquire a patent on body posture is similar to existing patents, or the assessment standards use existing ergonomic posture assessment tools' standards.

This study identified technology trends in the related fields through patents concerned with musculoskeletal disorders and the harmful factors of musculoskeletal disorders, and the utilization of motion capture technology. Even though many patents related to musculoskeletal disorders, the harmful factors of musculoskeletal disorders and motion capture were already registered, many of them were on posture correction and rehabilitation products, or on training systems in the sports field. Therefore, a new ergonomic posture assessment method is needed, rather than an aspect measuring body postures or viewing musculoskeletal disorders as diseases, in order to use motion capture technology, and also acquire a patent related to musculoskeletal disorders and the harmful factors of musculoskeletal disorders from the ergonomics point of view. In addition, the development of equipment to prevent musculoskeletal disorders and rehabilitate, or of the applied products is expected to be required.

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