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Publisher: Taylor & Francis

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Ergonomics

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/terg20>

A trend analysis of ergonomic research themes in Taiwan

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Accepted author version posted online: 24 Apr 2015. Published online: 26 May 2015.



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To cite this article: Chih-Long Lin (2015): A trend analysis of ergonomic research themes in Taiwan, Ergonomics, DOI: [10.1080/00140139.2015.1044572](https://doi.org/10.1080/00140139.2015.1044572)

To link to this article: <http://dx.doi.org/10.1080/00140139.2015.1044572>

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A trend analysis of ergonomic research themes in Taiwan

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(Received 8 March 2014; accepted 17 April 2015)

This paper examines the development of ergonomics in Taiwan by analysing 1404 scientific articles published by 113 permanent members of the Ergonomics Society of Taiwan (EST). Each article was classified by key words and abstract content. Each article was also coded by period of publication (1971–1992 (first period), 1993–1997 (second period), 1998–2002 (third period), 2003–2007 (fourth period), and 2008–2012 (fifth period), and against 13 topic categories. The results show that rate of publication has increased by approximately 100 articles every five years since 1993. The most popular topic was ergonomics assessment and analysis techniques in the first period, force exertion-related research in the second period, product design and evaluation in the third period, occupational safety and health in the fourth period and human–computer interface in the fifth period. Each of these is highly relevant to current contemporary issues around the world. Finally, potential areas for future ergonomics research in Taiwan are discussed.

Practitioner Summary: This study investigates the trends in academic papers published by members of the EST. Over time, topics have shifted from ergonomics evaluation methods to occupational safety and health, and human–computer interaction. The findings should be considered as important references for planning the future of ergonomics in Taiwan.

Keywords: Ergonomics Society of Taiwan; trend analysis; future of ergonomics; publication; research papers

1. Introduction

The development of human factors/ergonomics (HFE) has spanned more than 60 years, starting in Europe upon the establishment of the Institute of Ergonomics and Human Factors in England in 1949 and Gesellschaft fuer Arbeitswissenschaft in Germany in 1953. In 1957, the Human Factors and Ergonomics Society was founded in the USA, followed by the Association of Canadian Ergonomists in 1959. In the Asia region, the Japan Ergonomics Society was founded in 1964, the Ergonomics Society of Korea was founded in 1982, and the Chinese Ergonomics Society was founded in 1989. Currently, there are HFE-related organisations in more than 40 countries and regions throughout the world. Developments in both the scope and depth of HFE are impressive, with the proliferation of professional talent and the diversity of research topics.

In an effort to analyse the development of HFE from the perspective of paper publication, Waterson and Sell (2006) selected papers published in *Ergonomics* journal between 1958 and 1999 and analysed trends in article topics. They observed that topics based on human characteristics were the majority and, within this group, physiological topics increased over time while articles on psychology declined in frequency. Topics based on performance-related factors such as age, gender, individual differences and task-related factors were the next most common category. Articles published on these two topics accounted for more than 50% of the total. Zavod and Hitt (2000) analysed 511 articles published between 1988 and 1997 in *Human Factors* journal. The results showed that topics related to visual performance (111 articles) were the majority, accounting for 22% of the total, followed by industrial ergonomics and cognitive engineering (10%) and training (9%). Furthermore, Waterson, Falzon, and Barcellini (2012) investigated 987 articles published from 16 International Ergonomics Association (IEA) meetings and Congress events that convened between 1961 and 2009 and discovered that article topics based on ergonomic methods and methodology, workload, physiology and product design declined during the period, while articles on topics such as cognitive ergonomics, human–computer interaction (HCI), organisational design and management, and work and health gradually became dominant. During the same period, papers based on topics such as aging, international standards, and education and training remained stable. Lee (2010) analysed 649 articles published between 1982 and 2009 in the *Journal of the Ergonomics Society of Korea (JESK)*. The results indicated that between 1982 and 1989, research topics based on biomechanics, anthropometry and work physiology were the majority (41%), with displays and controls as well as work systems and workload analysis tying for second place (12%). In the 1990s, biomechanics, anthropometry and work physiology as well as displays controls remained the most popular topics, but accident safety became a new favourite, coming in third. From 2000 to 2009, biomechanics, anthropometry and work

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physiology continued to dominate the publication as the most popular topic category by quantity of articles, but the second and third topics changed to become consumer products and tools, and health and medical systems, respectively.

The Republic of China has systematically promoted the development of HFE in Taiwan since 1984. The National Science Council (NSC, now the Ministry of Science and Technology) invited domestic HFE professionals, including Professor Tzai-Zang Lee, Professor Lien-Fu Chen, Professor Sheng-Hsiung Hsu, Professor Sheue-Ling Hwang and others, to establish an 'Ergonomics Steering Group' and consider the future development of the field. After several meetings, the group identified goals for the future development of HFE, which would be named '人因工程' in Chinese. Subsequently, HFE became the developmental focus of the engineering and applied sciences department at NSC. In July 1992, a group of leading faculty and researchers from universities and other institutions across Taiwan established the Ergonomics Society of Taiwan (EST). This initiative was supported by the scholarly, educational and industrial communities. On 14 February 1993, the EST was officially inaugurated at the National Tsing Hua University at Hsinchu, with a mission to integrate human resources into HFE, facilitate cooperation to advance relevant academic studies and technical standards, and encourage the international exchange of studies and information within the field. More than 160 members attended the inaugural meeting, and Professor Sheue-Ling Hwang became the founding president of EST. The ROC has been promoting the knowledge, technology and concepts of HFE for more than 20 years. Research and implementation efforts that originated from the support of the NSC are now gradually expanding to other government institutions such as the Council of Labor Affairs, Atomic Energy Council, and the Ministry of Transportation and Communications. Together with increasing demand for ergonomics in the private sector, the importance and potential of ergonomics research are increasingly evident. In addition to industrial engineering and design departments, tertiary education now also includes manufacturing engineering, vehicle engineering, industrial health and safety, logistics management, and health and leisure sports departments, illustrating the demand for courses in ergonomics across various academic fields.

Articles investigating the development of HFE research topics in Taiwan are rare. Hwang et al. (1993) indicated that the human-machine system and industrial safety were the two major domains of study by EST members at the time. This was supported by Lee and Wang (2000), who showed that academia recognised occupational health, human-machine system and product design as the three major domains vital to the development of HFE in Taiwan, while the industry identified topics on occupational health, human performance and human information processing as more important. Now, with 20 years of history in the development of HFE in Taiwan, this study aims to investigate the evolution of trends in academic research topics. The findings from this research should be considered as important references for planning the future development of HFE in Taiwan.

2. Method

2.1 Method of data collection

This study analysed the tables of contents of academic journals provided by the permanent members of the EST, with a coverage period of 1971 to July 2012. The total number of permanent members of the EST was 201 as of June 2012. This research obtained the works of 113 members with a data coverage rate of 56.2%.

2.2 Method of data processing

This study collected a total of 1404 articles, ranging from the earliest publication in 1971 to the latest in 2012. The list of articles was keyed into Excel 2010 with each entry containing the following information: author, year of publication, title of the paper, title of the periodical, volume, issue, page number and keywords. In the event that multiple authors were listed for a single paper, the article was counted only once to avoid overestimation of the publications. This study included only articles from domestic and international periodicals and journals, and excluded those that were published in the proceedings of conferences or as a collection of papers for conferences. Additionally, all periodicals were updated with the latest titles to facilitate subsequent analysis.

2.3 Categorisation of article topics

First, the study tried to categorise articles by using the Ergonomics Abstracts system (EA system). When an article is indexed with the EA system, three different kinds of results will appear. First, information about ergonomics' primary classification is provided by the EA system; for example, the Wu, Ho, and Chi (2008) ergonomics primary classification is '07-02-00: Physical workload', which means the category is 'Performance-Related Factors'. The second kind of result is that the category of ergonomics' primary classification is not provided; rather, 'Subject Terms' are provided. Third, an article may be indexed, but the EA system does not show any category information. The characteristic distribution of 1404

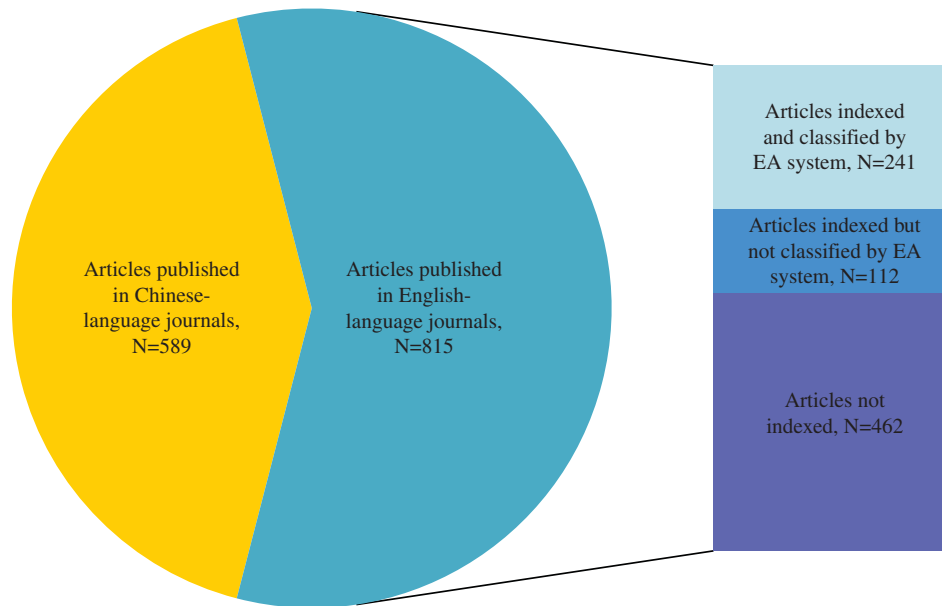


Figure 1. The characteristic distribution of 1404 articles.

articles is illustrated in Figure 1. A total of 589 of these are from Chinese language journals published in Taiwan, so they could not be categorised using the EA system. The other 815 articles (from English-language journals) could be classified into three groups. The first group includes 241 articles that were indexed and classified by the EA system; the second group includes 112 articles that were indexed but excluded category information and the third group includes 462 unindexed articles. Thus, 574 English language articles could not be categorised using the EA system.

Next, the subjective categorisation method was adopted. HFE has been integrated into a wide variety of fields. In addition to the traditional fields of fundamental such as anthropometry, psychology, work physiology, and test and evaluation, HFE is also relevant in applications such as consumer products, communication systems, automation and expert systems, transport systems, health and medical systems, and higher level macro-ergonomics such as work design, organisational design and management, training and education. During the beginning of the study, the author tried to assign each paper to an EA category. However, in order to emphasise specific research themes and present outstanding characteristics of HFE in Taiwan (e.g. anthropometry, semiconductor/TFT-LCD manufacturing-related HFE topics, inspection and driving tasks), some corresponding categories were created. Previous studies have differentiated HFE research topics into between 9 and 25 categories depending on the characteristics of the research samples (Hwang et al. 1993; Lee 2000; Lee and Wang 2000; Zavod and Hitt 2000; Waterson and Sell 2006; Lee 2010; Waterson, Falzon, and Barcellini 2012). The categorisation of article topics in both the current study and previous studies is illustrated in Table 1. This study examined 13 categories, with each article classified according to its title, key words or abstract matches to the category theme or meaning. For example, the article by Lee and Lee (2003) is classified into Topic 4 ('Force exertion task'); the article by Lin et al. (2010) is classified into Topic 5 ('Human-computer interaction') and the article by Chang et al. (2008) is classified into Topic 12 ('Health and safety'). It should be understood that studies can stretch over many topics, and, in some cases, articles could be assigned to different categories depending on one's point of view (Lee 2000, 2010).

2.4 Analysis of the articles

This study used 1993 – the year when the EST was established – as a baseline to segment the publication years before 1993 as the first period and every subsequent five-year interval as a separate period. The years of article publication were segmented into five periods: first period, from 1971 to 1992; second period, from 1993 to 1997; third period, from 1998 to 2002; fourth period, from 2003 to 2007; and fifth period, from 2007 to 2012.

3. Results

3.1 The quantity of articles and the publishing periodicals

In examining the total number of articles published during each period, data show that relevant article publication continuously increased with each passing year; for example, there were 72 articles published during the first period and 475

articles published during the fifth period, representing a six-fold increase with an average growth of 1.7 times each previous period (Figure 2). This indicates a gradual proliferation of HFE research publications in Taiwan. In-depth analysis of the publishing periodicals reveals that 1404 articles were published in 342 different journals. We note that 98 out of 342 journals (28.7%) are published in Taiwan and 244 journals (71.3%) are published in Western countries, Japan, and South Korea. In addition to ergonomics-oriented journals, this number includes journals in other fields, such as computer science (*Computer-Aided Design and Applications*, *Computers in Industry*, *Computers in Human Behavior*, etc.), design (*Design Studies*, *International Journal of Design*, etc.), health (*Advances in Health Sciences Education*, *Journal of Women's Health*, *BMC Public Health*, etc.), management (*International Journal of Management*, *International Journal of Human Resource Management*, *Asia Pacific Management Review*, etc.) and medicine (*Biomedical Engineering: Applications, Basis and Communications*, *Clinical Biomechanics*, *Clinical Rehabilitation*, *Spine*, etc.).

The top seven periodicals ranked by the quantity of articles in descending order are *Journal of the Chinese Institute of Industrial Engineers (JCIIE)* (95 articles, 6.8%), *Journal of Occupational Safety and Health (JOSH)* (92 articles, 6.6%), *International Journal of Industrial Ergonomics (IJIE)* (87 articles, 6.2%), *Journal of Ergonomic Study (JES)* (87 articles,

Table 1. Categorisation of article topics according to previous and current studies.

Author(s)	Source	Categorisation of article topics
Lee (2000)	A total of 418 papers published in by members of the Korean Society of Ergonomics (1982–1999)	(1) Aging, (2) Anthropometry and physical and physiological characteristics of human, (3) Aviation safety, (4) Design of medical devices, (5) Human performance, (6) HCI, (7) Industrial design, (8) Manual materials handling and safety, (9) Sensibility engineering
Zavod and Hitt (2000)	A total of 511 papers published in <i>Human Factors Journal</i> (1988–1997)	(1) Aerospace, (2) Aging, (3) CEDM, (4) Communications, (5) Computer Systems, (6) Consumer products, (7) Educator's professional, (8) Environmental design, (9) Forensics, (10) Individual differences, (11) Industrial ergonomics, (12) Macro-ergonomics, (13) Medical systems, (14) Safety, (15) Surface transportation, (16) System development, (17) Test & evaluation, (18) Training, (19) Virtual environments, (20) Visual performance
Waterson and Sell (2006)	Papers published in <i>Ergonomics Journal</i> (1958–1999)	(1) Display and control design, (2) Environment, (3) General ergonomics, (4) Health and safety, (5) Human characteristics, (6) Information presentation and communication, (7) Methods and techniques, (8) Performance-related factors, (9) Social and economic impact of the system, (10) System characteristics, (11) Work design and organisation, (12) Workplace and equipment design

Table 1 – continued

Author(s)	Source	Categorisation of article topics
Lee (2010)	A total of 649 papers published in <i>Journal of the Ergonomics Society of Korea</i> (1982–2009)	(1) Accidents, safety, and human error, (2) Aerospace systems, (3) Aging, (4) Attentional processes, (5) Automation and expert systems, (6) Biomechanics, anthropometry and work physiology, (7) Cognitive processes, (8) Communication systems, (9) Computer systems, (10) Consumer products and tools, (11) Displays and control, (12) Health and medical systems; patient safety, (13) Individual differences, (14) Macro ergonomics and the environment, (15) Manufacturing and process control systems, (16) Naturalistic decision-making, (17) Psychological states, (18) Psychomotor processes, (19) Sensation and perception, (20) Simulation and virtual reality, (21) Situation awareness, (22) Surface transportation systems, (23) Training, education, and instructional systems, (24) Visual systems, (25) Work system and workload analysis
Waterson, Falzon, and Barcellini (2012)	A total of 987 papers published in IEA Congress (1961–2009)	(1) Ageing, (2) Aviation, (3) Cognitive ergonomics, (4) Education and training, (5) Healthcare, (6) HCI, (7) International standards, (8) Organisational design and management, (9) Methods, (10) Methodology, (11) Physiology, (12) Product design, (13) Transport, (14) Workload, (15) Work and health
The present study	A total of 1404 papers published by 113 permanent members of the EST	(1) Ergonomic theory, (2) Methods and techniques, (3) Anthropometry, (4) Force exertion task, (5) HCI, (6) System characteristics, (7) Inspection task, (8) Workplace and equipment design, (9) Driving task, (10) Specific industrial research, (11) Specific user research, (12) Health and safety, (13) Macro-ergonomics and the environment.

6.2%), *Perceptual and Motor Skills (P&MS)* (68 articles, 4.8%), *Applied Ergonomics* (60 articles, 4.3%) and *Ergonomics* (30 articles, 2.1%), which combine to account for 37.0% of the total published. The quantity of articles published in each periodical during each of the five periods is illustrated in Figure 3. Prior to 2002, *JCIIE* published the most articles by the members; however, the quantity of its publication declined in the fourth and fifth periods, and was replaced by *JOSH* and *JES* as the top publishers. One possible explanation is that HFE was classified as an industrial engineering field in the years

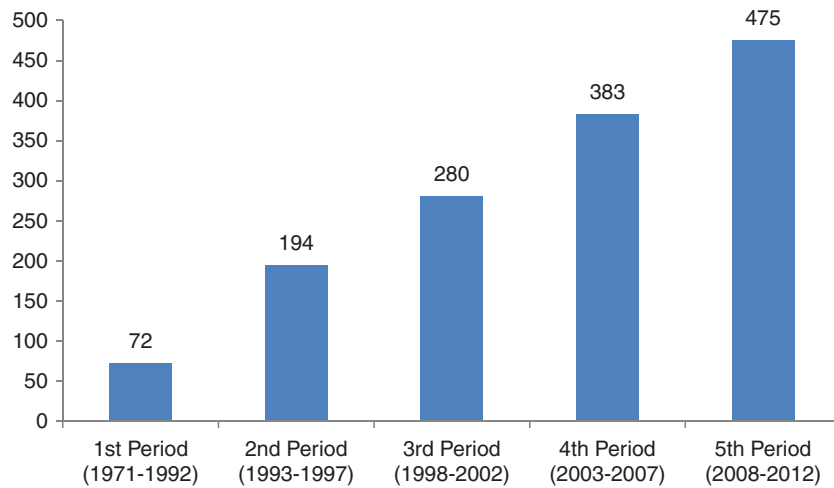


Figure 2. The total number of articles published during each period.

that comprise the earlier periods, so scholars published most of their research work in *JCIIE* due to the absence of other periodicals dedicated to HFE in Taiwan. It was not until the first publications of *JOSH* in 1993 and *JES* in 1999 that HFE finally had dedicated periodicals in Taiwan. Therefore, it is possible that HFE scholars shifted their submissions for article publication to these journals. The EST members published most of their articles in the international journal *IJIE* prior to 2002. After 2003, *P&MS* and *Applied Ergonomics* began growing rapidly, which is partially attributable to manufacturing becoming the primary industry in Taiwan. As a result, most HFE research concentrated on workplace evaluation and improvement, which prompted the scholars to publish their researches in *IJIE*, as it was more associated with these topics. The primary industry in Taiwan has been shifting towards design and manufacturing of digital information and consumer products during the past 10 years, thus attracting more scholars to focus on research related to product evaluation and design. Therefore, this study shows a shift in article publication to the journals *Perceptual and Motor Skills* and *Applied Ergonomics*.

In another analysis, Dul, Karwowski, and Vinken (2005) listed the top five Ergonomics journals and divided them into two categories, with *Ergonomics* and *Applied Ergonomics* classified as European journals and *Human Factors*, *Human Factors and Ergonomics in Manufacturing & Service Industries*, and the *International Journal of Industrial Ergonomics*

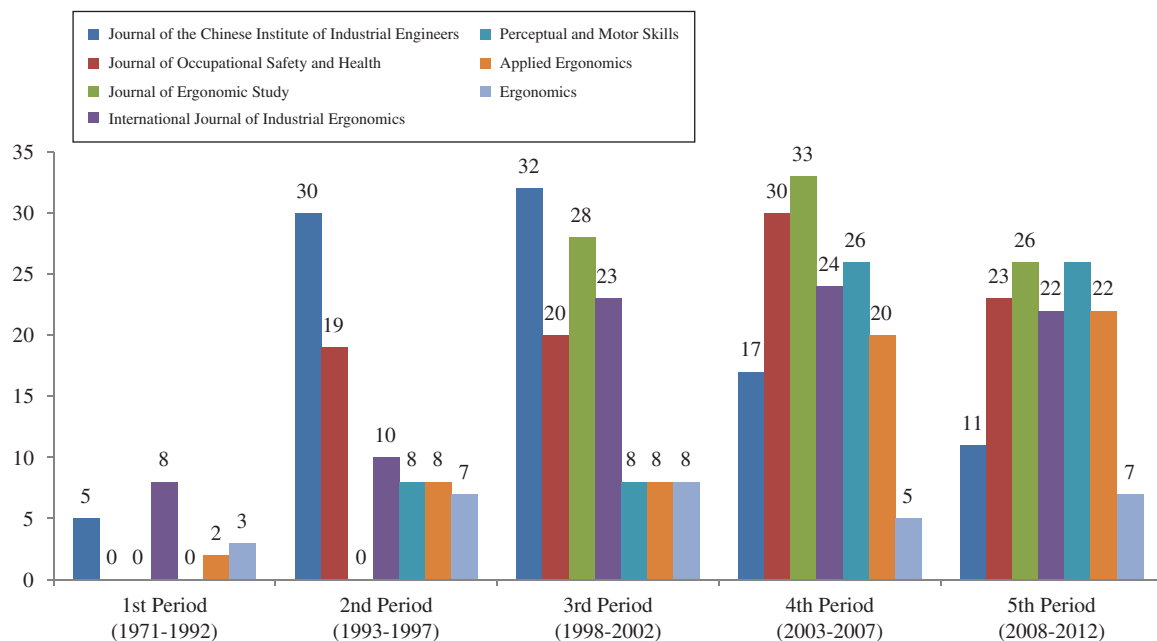


Figure 3. The quantity of articles published in the top six periodicals during each period.

classified as American journals. Under this classification, there were 90 articles published in European journals and 122 articles published in American journals. Thus, Taiwanese HFE scholars choose to publish in American journals more often.

3.2 Research topics of the articles

The categorisation results using Ergonomics Abstracts system are shown in Figure 4. The 22 articles published during the 1984–1992 period mostly consisted of articles on ‘Methods and techniques’. Of the 33 articles published during the period 1993–1997, ‘Human characteristics’ was the major category. The 72 articles published in the period 1998–2002 also focus on ‘Human characteristics’, with 21 articles that comprised 29.2% of the total for the period. The 104 articles published during the period 2003–2007 mostly cover ‘Display and control design’, ‘Health and safety’ and ‘Human characteristics’, with a total of 53 articles that made up 51.0% of the total for the period. In addition, there were only 10 articles published between 2008 and 2009. The articles on ‘Human characteristics’ showed the greatest growth in the period 1984–2002, and articles on ‘Display and control design’ and ‘Health and safety’ rounded out the top three categories after 2002. Overall, the category ‘Human characteristics’ contained the most articles (54 articles, 22.4%), and if further divided into two subcategories, results show that 31 articles were published about physiology and anatomical subcategory, and 23 articles were published about psychology. The next two most common categories are ‘Display and control design’ (33 articles, 13.7%) and ‘Health and safety’ (31 articles, 12.9%). Other categories, listed in descending order, were ‘Workplace and equipment design’ (30 articles, 12.4%), ‘Methods and techniques’ (29 articles, 12.0%), ‘Information presentation and communication’ (27 articles, 11.2%), ‘Work design and organization’ (20 articles, 8.3%), ‘Performance-related factors’ (11 articles, 4.6%), ‘System characteristics’ (3 articles, 1.2%), ‘General ergonomics’ (2 articles, 0.8%), and ‘Environment’ (1 article, 0.4%). No articles were classified as belonging to the ‘Social and economic impact of the system’ category.

The quantity of articles published in each topic category using subjective categorisation method is illustrated in Figure 5. Results show that Topic 8 (167 articles, 11.9%) contains the most articles, on topics such as hand tools (e.g. knives, screwdrivers, metalworking saws and tweezers); signage diagrams and symbols (e.g. signage used in discount stores, hospitals, airports and other public spaces); furniture (e.g. desks and work chairs); footwear (e.g. high heels and insoles); computer, communication and consumer (3C) products (e.g. keyboard, mouse, electronic books, PDA, iPod and iPhone); consumer products (e.g. spatula, toothbrush, chopsticks and remote controls); spaces or work stations (e.g. kitchen and toilet); and the evaluation, comparison and design of lumbar and back support products. The second most common topic ranked by quantity of articles is Topic 5 (155 articles, 11.0%), which includes display specifications of products, input methods of products, arrangement of the displayed contents, and the evaluation of the usage context. Topic 12 (141 articles, 10.0%) ranked third, with research on the survey of hazardous factors at workplaces; analysis of musculoskeletal disorder

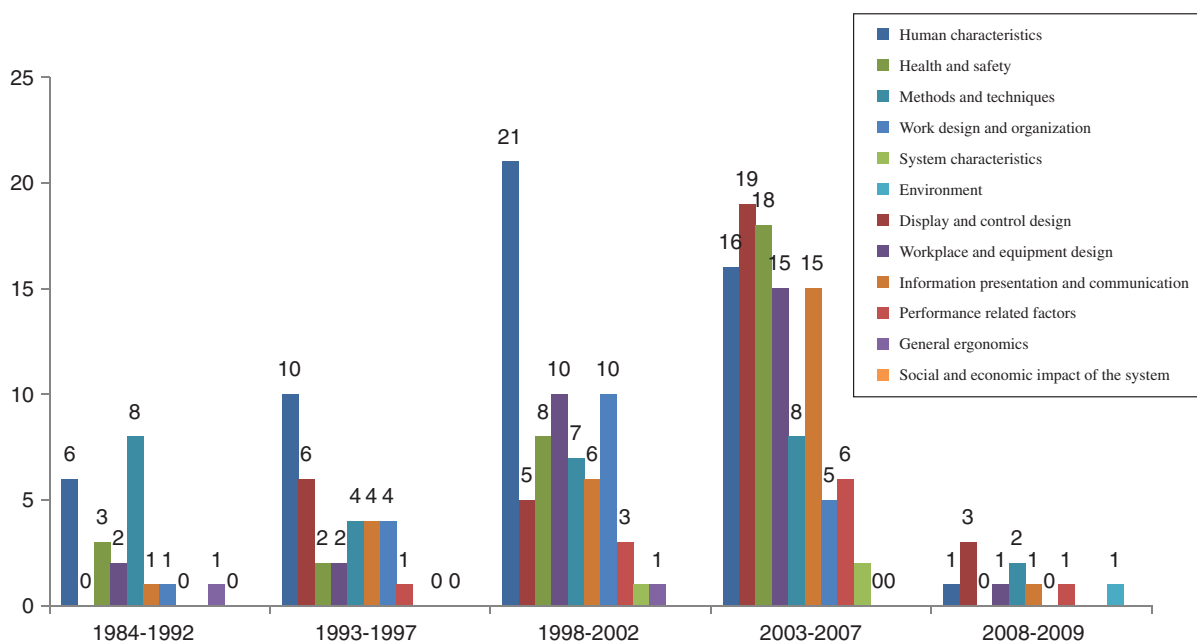


Figure 4. The quantity of articles published in each category as identified by Ergonomics Abstracts during each period.

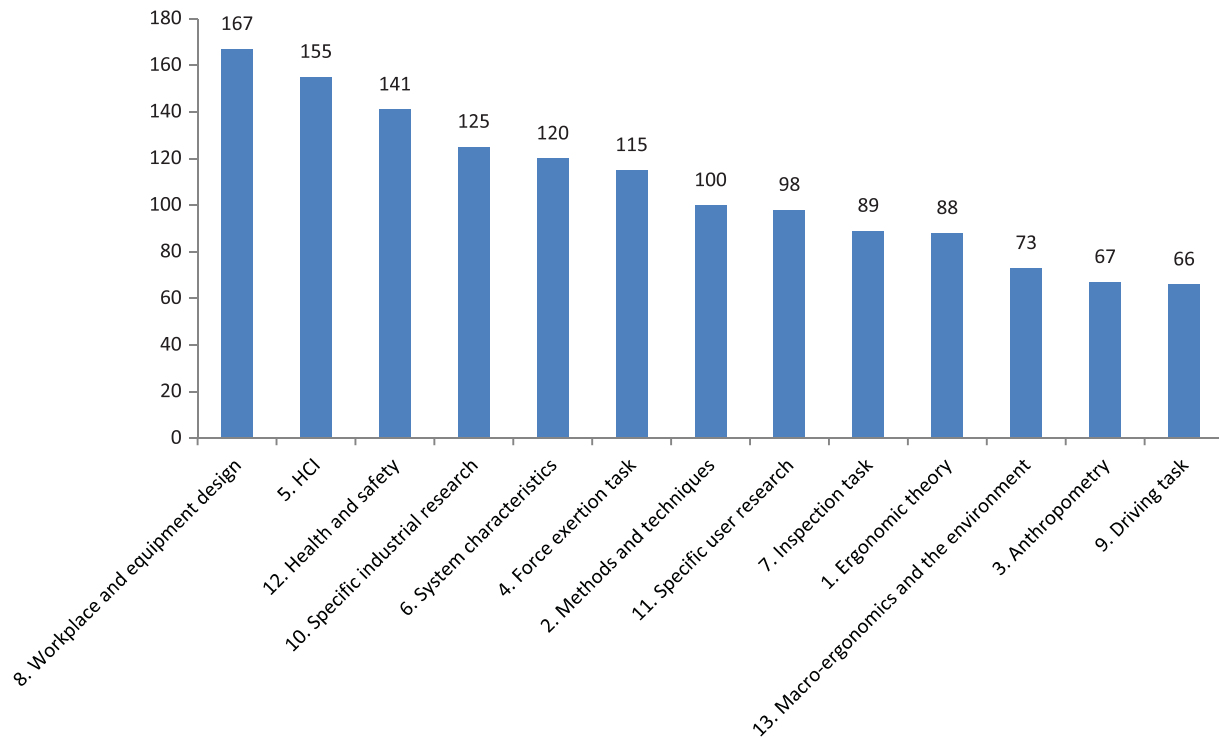


Figure 5. The quantity of articles published in each topic category.

prevalence; and studies on collapses, slips and falls. Other topic categories, listed in descending order, are Topic 10 (125 articles, 8.9%), Topic 6 (120 articles, 8.6%) and Topic 4 (115 articles, 8.2%).

The results of further analysis on the quantity of articles published in each topic category during each period are illustrated in Figure 6. The 72 articles published during the first period mostly consist of articles on Topics 2 and 8, with a total of 29 articles that comprise 40.3% of the total for the period. Articles on Topic 2 were mainly focused on the acquisition and analysis of electromyography (EMG), evaluation and application of the motion analysis system, and the creation of biomechanical models. The latter category is oriented towards the design of 3C products such as Chinese keyboards and remote controls, and the evaluation of hand tools such as rakes, chopsticks and spatulas.

Of the 194 articles published during the second period, Topics 4, 7, 1 and 2 are the four major categories, with a total of 101 articles that make up 52.1% of the total for the period. Articles on Topic 4 primarily investigate the impact of different work conditions, such as lifting tasks and tasks that apply force to the hands, on individuals' work abilities (e.g. maximum acceptable lifting weight, maximum grip or torque) or physiological reactions (e.g. EMG and heart rate). Articles on Topic 7 is centred on the methodologies of machine vision construction to enhance the performance of inspection tasks, while articles on Topic 1 focus on studies related to signal detection theories and personnel cognition abilities. Topic 2 includes articles on such topics as strength measurement and investigation of its operating mechanism, and the measurement of spinal angles and their impact on range of motion.

The 280 articles published during the third period mostly cover Topics 8, 4 and 5, with a total of 108 articles that comprise 38.6% of the articles in the period. Topic 8 consists of evaluating products such as hand tools (e.g. powered or manual screwdriver, professional knives and pipettes), desks and chairs, as well as lumbar and back support products. Topic 4 continues the focus from the second period, with studies on work abilities, physiological reactions and the biomechanics of lifting tasks. A substantial quantity of articles on Topic 5 had been published during the previous period and continued to grow into the third period. Articles on Topic 5 primarily evaluate the impact on performance of the presentation of information on computer displays, including studies on reading performance, identification, mouse-click performance, and visual fatigue influenced by the type, colour, brightness, and contrast of fonts or by the size and contrast of icons.

The 383 articles published in the fourth period focus mostly on Topics 12, 8 and 5, with a total of 137 articles that make up 35.7% of the total for the period. Topic 12 maintained a considerable level of publication throughout the previous periods, but reached its peak in the fourth period. Articles on Topic 12 investigate hazardous HFE factors or the causes of accidental incidents at the workplace; analyse the prevalence of musculoskeletal disorders or occupational injuries of

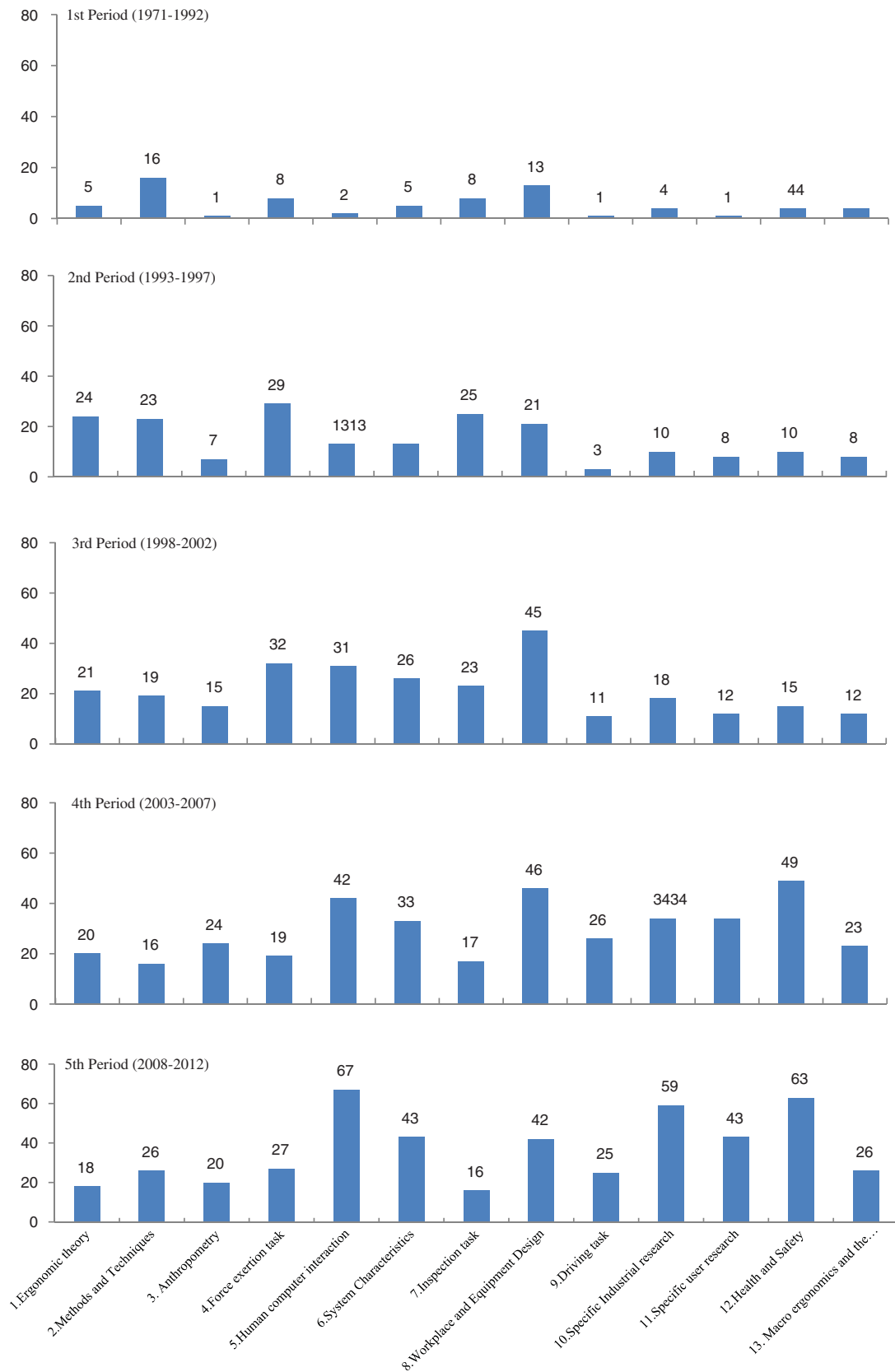


Figure 6. The quantity of articles published in each topic category during each period.

laborers; and research on the incidents of collapses, slips and falls at work. Topic 8 focuses on the exploration of 3C products such as handheld music players, electronic books, touch pens and mobile phones as well as consumer products such as toothbrushes, chopsticks and remote controls. In addition to overall research on the influences of the presentation of information in Topic 5, many articles investigated the impact of elements such as display type, size and brightness on reading distance, as well as subjective preferences and visual fatigue on reading performance.

The articles categorised as Topic 5, Topic 12 and Topic 10 comprise the majority of the 475 articles published in the fifth period, with a total of 189 articles that make up 39.8% of the total for the period. Many articles on Topic 5 continued the investigation on the impact of the presentation of information but with growing complexities of individual variables that simultaneously investigated the impacts of display hardware variables (e.g. polarity, contrast and resolution) and environmental variables (e.g. luminance and temperature of colour) on the users. Articles on Topic 12 investigated and evaluated elements of both HFE and occupational hazards in various types of workplaces and also investigated the musculoskeletal disorders of operations personnel in various professions. Topic 10 sustained a substantial level of publications during previous periods but reached its peak during the fifth period. The principal subjects of research during this period were semiconductor or TFT-LCD manufacturers, nuclear power stations, medical personnel, the construction industry and the military. The articles studied the subjects' onsite risk factors, musculoskeletal disorders and facility systems in order to evaluate and improve the human-machine interfaces and equipment used at the workplaces.

3.3 Evolutionary trends in HFE research topics

Figure 7 illustrated changes in the quantity of articles on each topic category during the second to fifth periods, using the first period as a baseline. This figure shows that articles on Topics 5, 12, 10, 11, 6, 9 and 13 show positive growth, with Topic 5 articles showing the most significant increase (65 articles between the first and fifth periods), followed by Topic 12 with an increase of 59 articles compared to the first period, and Topic 10, with an increase of 55 articles.

Upon further analysis of articles on Topic 5, it was discovered that the research subject shifted from video display terminal work stations to a variety of electronic information products, such as electronic books, electronic paper and mobile phones, used by the general public. The issues evaluated also evolved from the text identification and operational performance of the mouse and keyboard to reading comprehension, posture preferences and subjective preferences. Most previous studies, however, are centered on the influences of information presentation, such as the size, colour, brightness

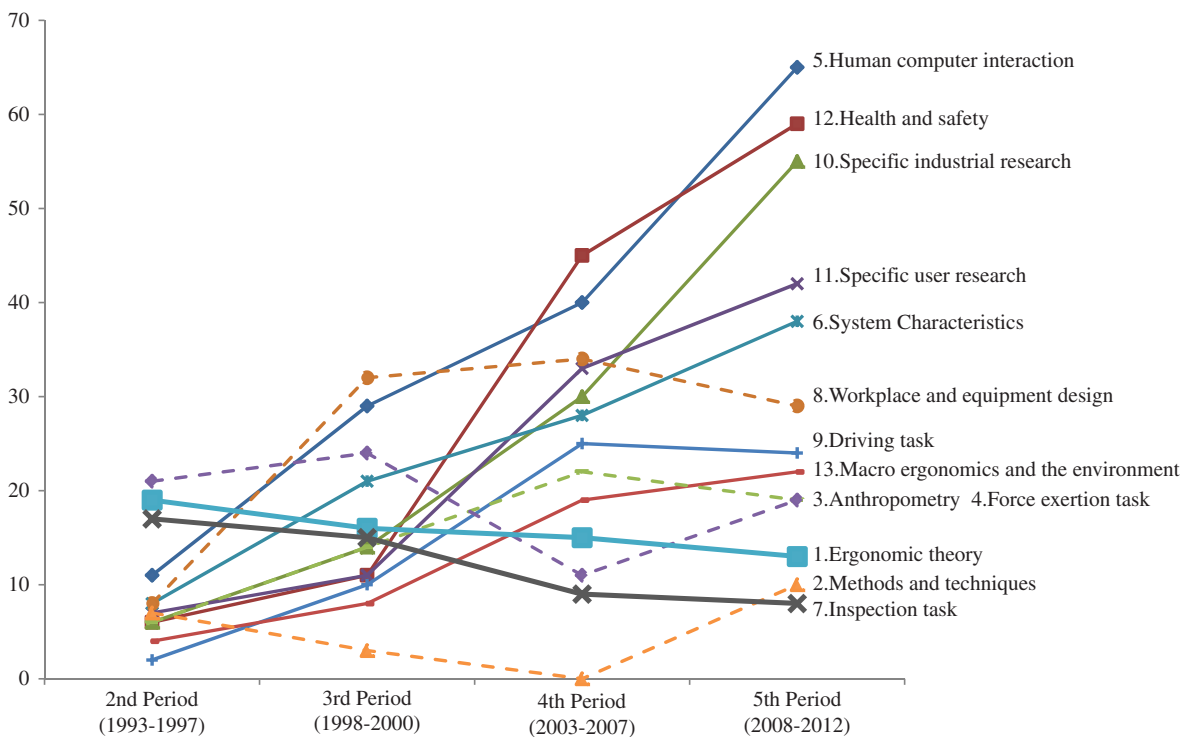


Figure 7. The changes in quantity of HFE articles in each of the topic categories during the second to fifth periods, using the first period as a baseline.

and background contrast of the text or digital symbols. The articles on Topic 12 have consistently concentrated on both the workplace and fundamental studies, regardless of the period. On one hand, the effects of various features that are hazardous to HFE, such as friction on the soles of shoes, falls and vibration, were investigated in laboratories, which led to the creation of theoretical models and checklists; conversely, however, the hazardous elements at a variety of workplaces, such as metalwork factories, catering and hotel industries, were evaluated against HFE methodologies for improvement. The research subjects in articles on Topic 10 were initially medical personnel, but were later replaced by professionals in high-tech industries such as semiconductor/TFT-LCD manufacturing, and those in control rooms of nuclear power plants. Research content on semiconductor/TFT-LCD manufacturers included musculoskeletal disorders in clean room operators, evaluation of wafer transportation operations, evaluation of clean room shoes and clothes, effects of roster operations and causes of work stress. The studies on the nuclear power plants focused primarily on the human-machine interface, emergency system, emergency operational procedures and personnel reliability in the control room.

The articles on Topics 1 and 7 show negative, or declining, trends. This study found that more research was conducted with the aim of creating theoretical fundamentals related to HFE (such as the theory of signal detection, decision-making processes, threshold values, personnel performance, and reliability) during the second period. In addition, more scholars applied mathematical models during this period, such as Fuzzy, Neural Network and Genetic Algorithm, to elevate the performance of automatic identification systems. The subject of research later shifted, however, to HCI and occupational safety and health, resulting in a decline of articles in this topic category.

The articles published on Topics 8, Topic 3, Topic 4 and Topic 2 showed variable trends, in which Topics 8 and 3 demonstrated an increasing trend during the third and fourth periods, but then declined slightly in the fifth period. Topics 4 and 2, however, showed an opposite trend, with reductions during the early periods followed by an increase during the fifth period.

4. Discussion

4.1 Changes in HFE research topics in Taiwan

The articles on Topic 3 showed the most significant growth in the period from 1993 to 1997, during which the Institute of Occupational Safety and Health and the NSC heavily invested in collecting large anthropometry data to create databases for the laborers in Taiwan, which generated more publication of studies related to anthropometry surveys. In addition, articles under the 'inspection task' topic during this period also increased substantially. One possible explanation may be that most HFE scholars in Taiwan had mathematical or mechanical backgrounds. Other than improving the operational performance of factories' manufacturing and quality management in industrial engineering, HFE scholars can also apply their knowledge to inspection operations by merging mathematical models and mechanical knowledge to enhance the inspection performance of machine. After 2000, the continuous support of the Taiwanese government's 'two trillion dual-star industries' project cultivated a wealth of publications on related HFE articles in the semiconductor and TFT-LCD industries.

Hwang et al. (1993) utilised the questionnaire survey method to enquire about the primary fields of research of EST members. The results found were similar to the works by Lee and Wang (2000) upon investigating academia. All interviewed subjects indicated that occupational health and HCI were the main fields of research, which is also consistent with the findings on articles published within the time period of this study. Prior to 1997, most article topics were classified as fundamental research on the structuring of HFE theories and the establishment of measurement methods, product inspection or operational evaluations on lifting tasks or forces applied on the hands. After 1998, articles on HCI consistently remained in the top three categories, and articles on occupational health entered the top three after 2003. Articles in occupational health and HCI ranked in the first and second places up to the fifth period. Therefore, it is evident that continuous effort by scholars in occupational health and HCI in Taiwan has gradually become more visible, as seen in published research works during the last period.

Judging by the number of articles published in each topic category, Taiwan HFE scholars put more focus on industrial ergonomics and HCI. The industry development trend in Taiwan and the diversity of EST members' academic backgrounds are the major factors influencing this tendency. On the one hand, industrial development in Taiwan is shifting from manufacturing to product design (especially 3C products) and service industries. On the other hand, 107 out of 113 members are university or college faculty. Based on the International Standard Classification of Education, developed by the United Nations Educational, Scientific and Cultural Organization, 42 EST members (39%) belong to the engineering, manufacturing and construction field, most of whom prefer to conduct industrial-related research; 25 members (23%) belong to the humanities and arts field, the majority of whom prefer to study product-related topics; and 20 members (19%) belong to the social sciences, business and law field, the majority of whom prefer to study cognitive-related topics. Thus, HFE studies in Taiwan tend to focus on industrial ergonomics and HCI.

4.2 Comparison with international HFE research topics

Because the periods of analysis, as well as the definitions and number of topics are different in this study and previous studies, a direct comparison is not possible. Only similar topics or developmental trends can be reviewed in tandem. The three major publication topics from different studies during the periods of 1970–1990, 1990–2000 and 2000–2010 are illustrated in Table 2. During the period of 1970–1990, as indicated in the study by Waterson, Falzon, and Barcellini (2012), the most popular topic at the IEA Congress was ergonomic methods. This is similar to the majority of article topics on ergonomic assessment methodology published before 1992 in Taiwan. In addition to the topic of ergonomic methods, human performance was also an active research topic in Taiwan (e.g. force exertion task) and Korea (Lee 2000) as well as in *Ergonomics* journal (Waterson and Sell 2006).

During the 1990s, following the global issue of human performance, the performance-related inspection task and force exertion task become the most popular topics in Taiwan. In addition, the articles on the topic of human characteristics were published in substantial quantities in *Ergonomics* journal (Waterson and Sell 2006) as well as in Korea (Lee 2000) until 2000. It is worth mentioning that the topics of occupational health and safety and HCI became more and more popular; for example, the articles in *Ergonomics* journal on the topic of health and safety had the most rapid growth (Waterson and Sell 2006), and occupational health and safety were also the dominant topics of study by the Germans (Zink 1997, as cited in Zink 2000). Later, Drury (2008b) pointed out that industrial ergonomics has grown significantly in North America as a result of the founding of *International Journal of Industrial Ergonomics* in 1986 and the *Human Factors and Ergonomics in Manufacturing & Service Industries* in 1991. The two journals which are specifically devoted to manufacturing concerns have expanded the industrial content of HFE studies in the USA. During the same period, the majority of articles published in *Human Factors* journal were focused on visual performance (Zavod and Hitt 2000); HCI, which was one of the most popular topics at IEA Congress (Waterson, Falzon, and Barcellini 2012), and displays and controls, as published in *JESK*

Table 2. The change of publication topics from 1970–2010 (only the first three major topics are shown in the table).

Author(s)	Subjects	Time period		
		1970–1990	1990–2000	2000–2010
The present study	Taiwan	Ergonomic assessment methodology Product and workplace evaluation Force exertion task	Product and workplace evaluation Force exertion task Inspection task	Occupational health & safety HCI Specific industrial research
Lee (2000)	Korean	APPCH Human performance Industrial design	APPCH Safety and MMH Human performance	–
Zink (1997)	Germany	–	Working system analysis and design Occupational health and safety Organisation analysis and design	–
Waterson and Sell (2006)	<i>Ergonomics</i>	Human characteristics Performance-related factors Environment	Human characteristics Performance-related factors Health and safety	–
Zavod and Hitt (2000)	<i>Human Factors</i>	–	Visual performance Industrial ergonomics Cognitive ergonomics	–
Lee (2010)	<i>Journal of the Ergonomics Society of Korea</i>	BAWP Displays and Controls Work System and Workload Analysis	BAWP Displays and Controls Accidents, Safety, and Human Error	BAWP Consumer Products and Tools HMS
Waterson, Falzon, and Barcellini (2012)	IEA Congress	Ergonomic methods	Ergonomic methods ODAM HCI	Work and health

Notes: APPCH, Anthropometry and physical and physiological characteristic of human; BAWP, Biomechanics, anthropometry and work physiology; HMS, Health and medical systems; patient safety; ODAM, Organisational design and management.

(Lee 2010). Considerable levels of articles in the 1990s, however, were focused on cognitive ergonomics and organisational design and management (Waterson, Falzon, and Barcellini 2012), but the articles published on these two topics in Taiwan were in the minority (e.g. cognitive ergonomics is included in Topic 1 and organisational design and management is included in Topic 13 in this study).

Furthermore, the continuous study on factory safety during the 1980s and 1990s came to fruition in the early 2000s, as more articles on safety and health issues were published in Taiwan. At the same time, the IEA Congress published substantial quantities of articles on topics that ranged from ergonomic methods to work and health (Waterson, Falzon, and Barcellini 2012). After 2000, HCI became a popular research topic in Taiwan, and it is evident that during this period, the widespread applications of computer equipment in factories and general lifestyles stirred up the popularity of research on human-machine interfaces around the world. The quantity of articles on consumer products also increased during this period to the second rank in *JESK*, as a result of technology innovation (Lee 2010).

The reason that research on anthropometry was the most popular topic during 1980s through the 2000s in *JESK* is closely related to the significant investment by the government to encourage research (Lee 2010). This suggests that government funding is beneficial to scholars conducting related research and potential publications in the future (Caple 2007). Similarly, governmental support of the 'two trillion dual-star industries' project in Taiwan after 2000 prompted significant growth in the quantity of articles on specific industrial-related research, especially for semiconductor/TFT-LCD industry workers, followed by the continuous growth of articles on occupational health and safety and HCI.

Apart from semiconductor workers, nurses, athletes and occupational drivers, there are other internationally popular study subjects (Haslam 2007, 2009). According to data on the most frequently downloaded papers from *Ergonomics* between 2005 and 2008, in addition to occupational health and safety issues (e.g. discomfort and pain, musculoskeletal problems and falls), medical-related issues (e.g. patient safety and nursing tasks) and reader-interested topics also increased (Haslam 2007, 2009), while the quantity of articles on health and medical systems increased to the third rank in *JESK* (Lee 2010), after topics on anthropometry and consumer products. Issues related to medical personnel and patient safety are daily concerns, and more researchers with backgrounds in medical science are attracted to join the ergonomics domain. As such, medical-related issues will become more and more popular for some time.

Regarding the future development of HFE, Lee (2010) proposed that Korea should focus primarily on the issues of sensibility engineering, aviation safety and aging. In addition to these specific development projects, Zink (2000) advises that the future of HFE should be expanded from micro-ergonomics (i.e. mainly focused on the research and application of engineering technologies) to macro-ergonomics, with domains on organisational, managerial and strategic aspects, in an effort to broaden the impacts of HFE. Furthermore, the theoretical aspects of research should be coupled with practical implementations to emphasise not only the improvement of work conditions, but also to articulate the economic benefits from improvements on work process. Waterson, Falzon, and Barcellini (2012) also indicated that topics on organisational design and management will continue to be popular. Drury (2008a) suggested that as technology progresses and the economic environment shifts from agriculture to manufacturing, which in turn is transforming to the service industry, an increasing number of workers will be involved in service-based operations (i.e. providing a variety of options and assisting consumers in making decisions). Hence, in addition to physiological workload issues, topics related to decision-making are also likely to be studied. Moreover, both job demands and human capabilities are becoming increasingly varied. For an ergonomist, the challenge will be how to match them. At the same time, it is an opportunity to increase ergonomist value for industry development. Dul et al. (2012) indicated that lack of awareness of the value of HFE, as well as sub-par HFE quality in design process, resulted in the underestimation of the effects of HFE. They provide two strategies to increase the demand of high-quality HFE and expansion of HFE application fields. The first strategy is to improve communication and build partnerships with target groups, and then educating them. The second strategy is to promote the quality of HFE research and standards, as well as the continuing education of HFE specialists. It is in this context that HFE has to continuously strive towards its goal, which is to create alignment between system requirements and the abilities of people who will be involved.

5. Conclusion

EST celebrated its 20th anniversary in 2013. Although its establishment occurred after similar organisations in other countries, the relentless efforts and cooperation between industry, government and academia led to significant contributions towards occupational health and safety, better manufacturing efficiency, and the publication of academic articles. Through the analysis of periodical article publications conducted by permanent members of the EST, this study discovered that the top seven periodicals by quantity of articles published are *Journal of the Chinese Institute of Industrial Engineers*, *Journal of Occupational Safety and Health*, *International Journal of Industrial Ergonomics*, *Journal of Ergonomic Study*, *Perceptual and Motor Skills* and *Applied Ergonomics and Ergonomics*. Over the course of the past 20 years, HFE papers published by permanent members of EST have been growing at an average rate of 100 articles for every five-year interval.

The topics have shifted from fundamental studies on HFE evaluation methods during the early periods to occupational safety and health in the later periods, with more studies on HCI in recent years. All of these are highly relevant to popular issues around the world. This study suggests that HFE in Taiwan will eventually emphasise issues related to HFE engineering (e.g. reducing the difference between the skills of the workforce and job requirements), organisational HFE engineering (e.g. assisting corporations in adjusting the business for rapid adaptation to market demands) and healthcare (e.g. addressing the impacts of the aging population), in the hope of a brighter future for HFE both in Taiwan and globally.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

We thank the National Science Council of Taiwan [grant number NSC 102-2221-E-144-001] and The Ergonomics Society of Taiwan for funding this study.

References

- Caple, D. C. 2007. "Ergonomics-Future Directions." *Journal of Human Ergology* 36 (2): 31–36.
- Chang, W. -R., K. W. Li, A. Filiaggi, Y. -H. Huang, and T. K. Courtney. 2008. "Friction Variation in Common Working Areas of Fast-Food Restaurants in the USA." *Ergonomics* 51 (12): 1998–2012. doi:10.1080/00140130802562641.
- Drury, C. G. 2008a. "The Future of Ergonomics/The Future of Work: 45 Years After Bartlett (1962)." *Ergonomics* 51 (1): 14–20. doi:10.1080/00140130701800894.
- Drury, C. G. 2008b. "Human Factors in Industrial Systems: 40 Years On." *Human Factors* 50 (3): 368–374. doi:10.1518/001872008X312189.
- Dul, J., R. Bruder, P. Buckle, P. Carayon, P. Falzon, W. S. Marras, J. R. Wilson, and B. Van Der Doelen. 2012. "A Strategy for Human Factors/Ergonomics: Developing the Discipline and Profession." *Ergonomics* 55 (4): 377–395. doi:10.1080/00140139.2012.661087.
- Dul, J., W. Karwowski, and J. Vinken. 2005. "Technical Note: Objective and Subjective Rankings of Scientific Journals in the Field of Ergonomics: 2004–2005." *Human Factors and Ergonomics in Manufacturing & Service Industries* 15 (3): 327–332. doi:10.1002/hfm.20029.
- Haslam, R. 2007. "Editorial." *Ergonomics* 50 (12): 1953–1956. doi:10.1080/00140130701777555.
- Haslam, R. 2009. "Editorial." *Ergonomics* 52 (12): 1455–1459. doi:10.1080/00140130903478465.
- Hwang, S. L., Y. -C. Shih, C. H. Cheng, C. S. Lin, C. H. Woon, H. H. Son, and C. J. Cheng. 1993. "The Investigation of Current Researches for Human Factors and Ergonomics." *Journal of Occupational Safety and Health* 1 (2): 19–27.
- Lee, K. S. 2000. "Vision of Asian Ergonomics: The Trend of Ergonomics Development in Korea." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 44 (38): 692–695. doi:10.1177/154193120004403802.
- Lee, D. H. 2010. "A Study on Trend of the Research Papers Published in the Journal of the Ergonomics Society of Korea." *Journal of the Ergonomics Society of Korea* 29 (4): 701–707. doi:10.5143/JESK.2010.29.4.701.
- Lee, T. -H., and Y. -H. Lee. 2003. "An Investigation of Stability Limits While Holding a Load." *Ergonomics* 46 (5): 446–454. doi:10.1080/0014013021000039583.
- Lee, T. Z., and J. J. Wang. 2000. "Ergonomics in Taiwan: The Present and Future." *Journal of Ergonomics Study* 2 (1): 1–10.
- Lin, C. J., C. N. Liu, C. J. Chao, and H. J. Chen. 2010. "The Performance of Computer Input Devices in a Vibration Environment." *Ergonomics* 53 (4): 478–490. doi:10.1080/00140130903528186.
- Waterson, P., P. Falzon, and F. Barcellini. 2012. "The Recent History of the IEA: An Analysis of IEA Congress Presentations Since 1961." *Work: A Journal of Prevention, Assessment and Rehabilitation* 41: 5033–5036.
- Waterson, P., and R. Sell. 2006. "Recurrent Themes and Developments in the History of the Ergonomics Society." *Ergonomics* 49 (8): 743–799. doi:10.1080/00140130600676056.
- Wu, S. P., C. P. Ho, and H. C. Chi. 2008. "Ergonomic Study of a Vertical Rope-Pulling Task From a Scaffolding." *Ergonomics* 51 (3): 345–354. doi:10.1080/00140130701627875.
- Zavod, M., and J. M. Hitt. 2000. "Summary of the Publishing Trends of the Journal of Human Factors from 1988–1997." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 44 (33): 6-108–6-111. doi:10.1177/154193120004403307.
- Zink, K. J. 1997. "Stand Der Arbeitswissenschaft in Deutschland-Einige Empirische Daten." In *Zukunft t der arbeitswissenschaft als zukunft der gfa*, edited by G. F. A. Gfa, 1–16. Dortmund.
- Zink, K. J. 2000. "Ergonomics in the Past and the Future: From a German Perspective to an International One." *Ergonomics* 43 (7): 920–930. doi:10.1080/001401300409116.