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Cost-effectiveness and effectiveness of applying intelligent osteoporosis health risk assessment system in community-dwelling women: a novel evidence-based study

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Cost-effectiveness and effectiveness of applying intelligent osteoporosis health risk assessment system in community-dwelling women: a novel evidence-based study

Background. Few studies have explored how to assist at risk females understand the status of osteoporosis without invasive data.

Aims. To develop an intelligence osteoporosis health risk evaluation system and used for a preliminary empirical analysis of Asian women.

Setting. This study is focused on community-dwelling women who had accepted dual-energy X-ray absorptiometry examination in health evaluation centre of a medical centre in north Taiwan from 2005–2006.

Design. A longitudinal, evidence-based study was conducted.

Method. The first stage is to establish the data base. This part included information from random samples (n = 220), including data for bone mineral density, osteoporosis risk factor, knowledge, belief and behaviour. The second stage is to detect the accuracy of this system including sensitivity, specificity, positive predictive value and negative predictive value. The third part is to evaluate the preliminary effect of nursing evidence-based study. Participants (n = 90) determined the relative risks of osteoporosis with system were randomly grouped into experimental or control group.

Results. The content validity index among knowledge, beliefs and behaviours were 0·99, 0·89 and 0·95, respectively. In Cronbach's alpha value, osteoporosis prevention knowledge belies and behaviours were 0·84, 0·79 and 0·77, respectively. The sensitivity and specificity of the analytical tools were 75%. In preliminary empirical study, this study showed the knowledge and perceived benefits of osteoporosis could be promoted by individual nursing instruction and could obtain economical and effective results.

Conclusions. This study can be applied in different diseases health risk evaluation in the future and provides community residents a good reliability, good validity, practical, convenient and economic self-health management model.

Relevance to clinical practice. This study developed a useful approach for providing Asia women with a reliable, valid, convenient and economical self-health management model to increase the effectiveness of osteoporosis prevention programs for at risk women.

Key words: community nursing, cost effectiveness, osteoporosis, remote health care, women's health

Introduction

The United States Government established the National Osteoporosis Foundation in 1986 to prevent the onset of osteoporosis through education and research. The World Health Organization (WHO) later designated October 20th as World Osteoporosis Day (WHO 2007), further emphasising the imperative to prevent this globally pervasive disease. According to research, woman accepting bone mineral density examination can reveal the bone condition of her and also evaluate the possibility of being osteoporosis (Chang 2008). Examining bone mineral density (BMD) examination is just as important as monitoring blood pressure. While blood pressure values form the basis of predicting the onset of strokes, dual-energy X-ray absorptiometry (DXA) is the conventional and most accurate means of examining BMD (International Osteoporosis Foundation 2009). Bone mineral density is evaluated based on the osteoporosis diagnostic standard established by WHO (International Osteoporosis Foundation 2009, World Health Organization 1994). This standard specifies bone density lower than one standard deviation below that of an average 30-year-old Caucasian female as normal. Additionally, bone density that is 1–2·5 standard deviations lower than that of an average 30-year-old Caucasian female is designated as having osteopenia. Moreover, bone density that is 2·5 standard deviations or more lower than that of an average 30-year-old Caucasian female is designated as having osteoporosis. In Taiwan, the ratio of osteoporosis is over 16% in women over 60 years old, while the onset ratio of osteoporosis in women is 6–8 folds higher than that in men, highlighting its serious threat to the health of women (Bureau of Health Promotion, Department of Health 2007).

The World Health Report of 2002 established the motto of 'Reducing Risks, Promoting Healthy Life' as the current trend in global public health. A previous study cited health risk appraisal as important for health consciousness and the approach to change lifestyle behaviour by evaluating personal health habits and health risks to understand the risks of contracting and suggesting measures to reduce the onset of contracting diseases (Harari *et al.* 2008). In Taiwan, the abuses of medical resources and runaway medical expenditures have led to an annual deficit in the national health insurance scheme, forcing a modification in the overall scheme. However, medical resource users represent the most effective means of controlling medical expenditures by reducing the number of high risk individuals and inhibiting the growth of low-risk individuals. Developing an effective health risk appraisal scheme that can prevent and control diseases is thus of priority concern (Harari *et al.* 2008). Therefore, by incorporating health risks, this study describes a novel health risk appraisal approach that can accurately predict bone loss and the onset of osteoporosis in Taiwan female residents. Moreover, an intact nursing proposal is also introduced to prevent the onset of osteoporosis of Taiwan female residents.

Aims

1 Establish a database for an intelligent osteoporosis health risk evaluation system (IOHRES).
2 Determine the accuracy of IOHRES.
3 Evaluate how IOHRES affects cost in a nursing evidence-based study.

Research design

Ethical considerations

The Ethics Review Committee at Cardinal Tien Hospital approved the study protocol, which complied with the Institutional Review Board (IRB) guidelines for human studies in Taiwan. Assured of anonymity and confidentiality, all participants were allowed to withdraw from the study without explanation or penalty.

Subjects

The 950 cases accepted in this study focused on women who had received a DXA examination in health evaluation centre of a Taipei medical centre from 2005–2006. The study also received approval from the internal review board of the centre. The criteria of the cases accepted are as follows:

1 Understand Mandarin and willing to accept investigation.
2 Women over 30 years old.
3 Women who had received DXA examination in the medical centre.

The 950 patients in the cases were contacted through a telephone questionnaire interview. Of which, 340 samples satisfied the study criteria, equivalent to a participation rate of 35·8%. All samples collected were separated randomly into three parts (Fig. 1).

Establishment of IOHRES database

A database for an osteoporosis health risk evaluation method contains 220 samples of information, including bone density (normal, osteopenia, and osteoporosis), osteoporosis risk factors, osteoporosis knowledge, as well as beliefs and lifestyle behaviours. IOHRES is based on fuzzy theory, in which a health risk appraisal procedure is constructed using a simple structure and an easily derived

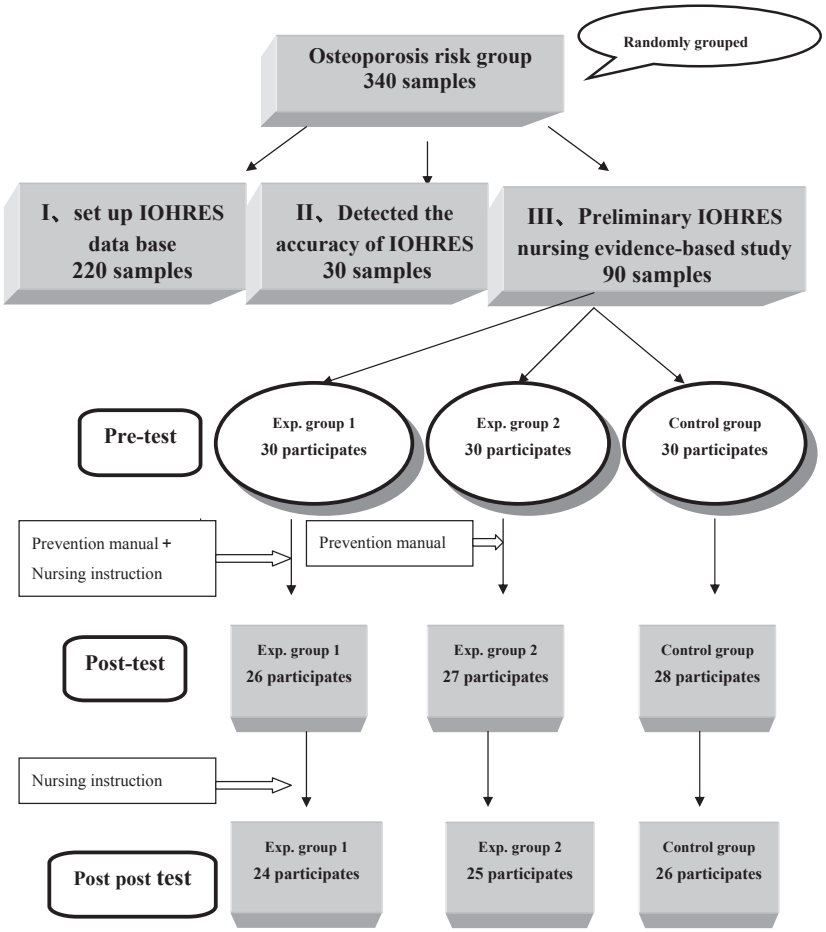

Figure 1 The study flow chart.

K-means algorithm. The K-means algorithm divides collected samples into k subclasses; each subclass is a cluster; k subjects are selected randomly in the database as the average of each cluster. Meanwhile, all collected data are distributed into the closest cluster, and the new average number is calculated. This procedure is repeated until the subject distribution remains unchanged, leading to a valid health risk appraisal.

Determination of IOHRES accuracy

According to Timmer *et al.* (2009) the validity of screening tools includes sensitivity (i.e. number of osteoporosis detected cases/total number of osteoporosis cases), specificity (i.e. number of non-osteoporosis detected cases/total number of non-osteoporosis cases), positive predictive value (PPV) and negative predictive value (NPV).

Evaluation of the preliminary cost effectiveness of IOHRES for a nursing evidence-based study

Experimental research of longitudinal survey design was used to evaluate the effectiveness of a nursing intervention. Participants were invited and instructed to take part in a telephone interview-based questionnaire regarding osteoporosis risks, osteoporosis knowledge, belief and behaviour. The scheme then determined the relative risks between bone normal, bone loss and osteoporosis for women. The women were randomly grouped into experimental group 1, experimental group 2 and control group. Each group contained 30 women and was provided different nursing intervention methods based on power considerations. Huang *et al.* (2010) suggested that when an estimated effect size (estimated population mean group difference divided by the estimated population standard deviation) is 0·80, the approximate sample size required is 26 for each group when alpha is set at 0·05 and the power is set at 0·80. Therefore, each group contained 30 women and was oriented on different nursing intervention methods. Figure 1 displays the study flow chart.

Assessment approach IOHRES contains the following subscales

Osteoporosis risk factors questionnaire

The questionnaire was developed after reviewing pertinent literature (Kanis *et al.* 2007, Chang 2008, International Osteoporosis Foundation 2009). The questionnaire evaluated height, weight, age, heredity, ovariectomy, menopause, drinking alcohol, smoking, hormone medicine intake, coffee drinking habits, basking in the sun, shortened height, humpback, low back pain, fracture history, teeth mobility, amount of calcium intake, milk and cheese products, food with high calcium, outdoor activity level, living safety (frequency of behaviour such as wearing high heels, bending at the waist, lifting heavy objects, taking tranquilisers and incidence of injuries from falling).

Osteoporosis knowledge, health beliefs and preventive behaviour

The osteoporosis knowledge section included seven yes or no questions; a correct answer received 1 point, a wrong or unanswered question received 0 points. A high score indicated adequate knowledge of osteoporosis.

The osteoporosis belief section included four questions regarding perceived susceptibility, perceived severity, perceived barriers and perceived benefits of osteoporosis. Answers were scored on a Likert scale as follows: strongly agree, agree, neither agree nor disagree, disagree and strongly disagree were scored as 5, 4, 3, 2 and 1, respectively.

The osteoporosis preventive behaviour section contained six questions, including daily intake of calcium rich food; exercise for at least 30 min at least three times weekly; emphasis on home safety and prevention of falls; intake of oestrogen that exactly follows the doctor's instructions if so prescribed; intake of vitamin D rich foods (e.g., deep green vegetable, fish liver oil); intake of bisphosphonates; or other medicines according to the doctor's instructions. The rating scale also applied a Likert scale; the points for almost always true, usually true, somewhat true, usually not true and almost never true were 5, 4, 3, 2, respectively.

Reliability and validity of study methods

The content validity index (CVI) scores for osteoporosis knowledge, beliefs and preventive behaviours were conducted. Following an expert assessment of content validity, the questionnaire pretest results were examined for inner consistency using Cronbach's alpha.

Inter-rater reliability and intra-rater reliability qualifications

During the questionnaire collection, researchers received inter-rater reliability training to ensure their full understanding of the questionnaire contents and their ability to perform interviews consistently.

Data analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS), version 14·0 for Windows. Risk

factors and osteoporosis knowledge, beliefs and preventive behaviours in participants were summarised based on a description and Pearson correlation analyses. Next, exactly how osteoporosis-related knowledge, beliefs and behaviours are related were explored, as well as cost effectiveness of the research design. Additionally, knowledge, beliefs and preventive behaviours of at risk females were analysed based on longitudinal studies in which repeated measurements were taken. Moreover, radar charts were constructed to present knowledge, beliefs and preventive behaviour of women with a high risk of osteoporosis.

Results

Reliability and validity of study procedures

During the questionnaire collection period, researchers received inter-rater reliability training to ensure their full understanding of the questionnaire and ability to perform interviews uniformly. The real correlation coefficient of inter-rater reliability and intra-rater reliability of this study exceeded 0·86 ($p < 0·05$) and 0·91 ($p < 0·05$), respectively, indicating an acceptable test consistency.

As for results of experts' content validity, the osteoporosis self-physical examination chart has a total of 23 questions, in which the CVI score is 0·96. Additionally, there are seven questions about osteoporosis knowledge, in which the CVI score is 0·99. Also, there are four questions about the four major elements of osteoporosis beliefs, in which the CVI score is 0·89. There are six questions about osteoporosis prevention behaviour among women, in which the CVI score is 0·95. Following validation of the experts' content, the questionnaire pretest results were examined with respect to the inner consistency with Cronbach's alpha. There are seven yes or no questions about osteoporosis prevention knowledge. The qualification result of Cronbach's alpha value is 0·83. As for the questions of four key elements of osteoporosis belief, Likert scale 5 points score measurement was used and the value was 0·88. As for the osteoporosis behaviour portion of the pilot study, Cronbach's alpha result increased to 0·87.

The average age of women in this study was 61 years old; in addition, the average height and weight were 155·7 cm and 55·6 kg, respectively. The prevalence of osteoporosis in women was 20·0%. Although the overall bone mineral density of women fell within normal conditions (43·3%), the average bone mineral density values were close to the osteopenia (T-score = −0·98).

Summary of risk factors and osteoporosis knowledge, beliefs and preventive behaviours of participants and their relationships

The osteoporosis knowledge scores ranged from 0–6 points, averaging 3·6 points, i.e., an accuracy rate of 60·0%. Women diagnosed with osteoporosis perceived susceptibility to a low score, with an average score of 2·9 points. The score of perceived seriousness was at a high average score of 3·1 points. Women diagnosed with osteoporosis behaviours, with an average score of 2·5 points, were only 41·6% the entire group (Table 1). Correlation analysis of osteoporosis knowledge, belief and behaviour in women indicated that osteoporosis knowledge is statistically and positively correlated with severity and behaviour ($r = 0·65$, $p < 0·05$; $r = 0·56$, $p < 0·05$) (Table 2).

Determination of the accuracy of IOHRES

The osteoporosis intelligent health risk evaluation system used in this study has an osteoporosis prediction accuracy of 75%. Meanwhile, the sensitivity of analysis procedures is 75% (i.e. the number of osteoporosis cases detected/total number of osteoporosis cases). Also, the specificity is 75% (i.e. the number of non-osteoporosis cases detected/total number of non-osteoporosis cases).

Effect of post-post-test on knowledge, belief and behaviour

By using ANCOVA, post-post-test knowledge, beliefs and behaviours were analysed. Comparing the groups in post-post-test knowledge, beliefs and behaviour score of risk females after 12 weeks of pretest revealed a statistical significance in the knowledge score of the three groups after adjustment ($F = 5·29$, $p < 0·05$). More closely examining the results revealed that the score of experimental group 1 is higher than that of experimental group 2 and the control group; in addition, the knowledge was increased by 21·71% and 23·24%, respectively. Additionally, the score of experimental group 1 is higher than that of experimental group 2; in addition, the perceived benefit is increased by 33·33% (Table 3).

Cost effectiveness of preliminary nursing intervention

Cost effectiveness of the longitudinal nursing study was evaluated based on different nursing intervention programs. According to those results, the score of knowledge in

Table 1 Summary of risk factors and osteoporosis knowledge, beliefs and preventive behaviors in participates (n = 90)

Variables	n	%	Mean	SD
Bone mineral density (T-score)			−0·98	1·5
❶ Normal	39	43·3		
❷ Osteopenia	33	36·7		
❸ Osteoporosis	18	20		
Height (cm)			155·7	5·6
Weight (kg)			55·6	9·4
Age			60·5	11·6
Osteoporosis knowledge (0–6分)			3·6/6 (60%)	1·7
Osteoporosis beliefs				
Perceived susceptibility			2·9	1·4
Perceived seriousness			3·1	1·5
Perceived benefits			3·0	1·5
Perceived barriers			3·0	1·5
Osteoporosis behaviours			2·5	0·8
Family history				
Yes	18	20		
No	72	80		
Ovarian surgery				
Yes	17	18·9		
No	73	81·1		
Menopause				
Yes	38	42·2		
No	52	57·8		
Smoking				
Yes	4	4·4		
No	86	95·6		
Taking hormone medicine				
Yes	23	22·5		
No	67	65·7		
Drinking coffee				
Yes	17	18·9		
No	73	81·1		
Basking in the sun				
Yes	25	27·8		
No	65	72·2		
Shortened height				
Yes	27	30		
No	63	70		
Hump back				
Yes	28	31·1		
No	62	68·9		
Low back pain				
Yes	43	47·8		
No	47	52·2		
Fracture history				
Yes	27	30		
No	63	70		
Teeth mobility				
Yes	28	31·1		
No	62	68·9		
Enough of calcium intake				
Yes	20	22·2		
No	70	77·8		
Up taking milk and cheese products				
Yes	61	67·8		
No	29	32·2		
Food with high calcium				
Yes	50	55·6		
No	40	44·4		
Outdoor activity				
Yes	19	21·1		
No	71	78·9		
Avoid wearing high heels				
Yes	19	21·1		
No	71	78·9		
Bending at the waist				
Yes	50	55·6		
No	40	44·4		
Lifting heavy objects				
Yes	16	17·8		
No	74	82·2		
Incidence of injuries from falling				
Yes	24	26·7		
No	66	73·3		

experimental group 1 is higher than that in the experimental group 2 and control group; in addition, the cost is relatively lower than that of the other two groups. Meanwhile, in terms of perceived benefits, cost-effectiveness analysis revealed that the experimental group 1 could save about five times the amount of cost than the control group could (Table 4).

Repeat measurements analysis of at risk females

Owing to that repeat measurements revealed that only knowledge had a significant amount of progress in prevention knowledge. Longitudinal study analysis was performed for at risk females including osteopenia ($-1 <$ T-score $< 2{\cdot}5$) and osteoporosis (T-score $\leqq -2{\cdot}5$) women in each group to understand the effectiveness of the three nursing measurements. Given its clear and direct features, the radar chart is a more comprehensive analysis method than other analysis methods. Figures 2–4 summarise the results of radar chart analysis.

Discussion

Current status of study subjects and correlation analysis

This study found that the prevalence rate of women osteoporosis is 20·0% (Table 1), a finding which is lower than that of Wang *et al.* (2009) and Peng (2002). This discrepancy is probably owing to that the study subjects willing to join the

Table 2 Relationship among bone mineral density (BMD), risk factors and osteoporosis knowledge, beliefs and preventive behaviors in participates (n = 90)

	Knowledge	Beliefs				Behaviors
		Susceptibility	Seriousness	Benefits	Barriers	
Variables	*r*	*r*	*r*	*r*	*r*	*r*
BMD (T-score)	0·96	0·12	0·89	0·06	1·31	0·37
Knowledge	–					
Beliefs						
Perceived susceptibility	0·02	–				
Perceived seriousness	0·65*	−0·18	–			
Perceived benefits	0·06	0·05	0·19	–		
Perceived barriers	−0·17	0·01	0·05	−0·02	–	
Behaviors	0·56*	−0·03	−0·08	0·09	0·01	–

*$p < 0{\cdot}05$.

screening are relatively high concerned with their health and much attention about osteoporosis-related information, explaining the lower prediction outcome of osteoporosis health risk than in other studies. Additionally, this difference may also be owing to that the accuracy of this software is 75%, possibly leading to an underestimation during evaluation of the risk ratio among women diagnosed with osteoporosis.

Table 2 displays the accuracy rate of women diagnosed with osteoporosis, in which the related knowledge test was only 49·8%. The score is lower than that in an osteoporosis prevention pilot study in community women by Chang *et al.* (2003) (66·7%) and Hurst and Wham (2007) (63%). Previous data suggest that most women lack knowledge of osteoporosis prevention, necessitating that community nursing staff heavily emphasising education in this area.

Table 3 Post post test in knowledge, beliefs, and behaviors among three groups

	Exp. group 1 ❶		Exp. group 1 ❷		Control group ❸				
Score	Mean	SD	Mean	SD	Mean	SD	*F*	Scheffe test	%
Knowledge	4·56	1·80	3·57	1·40	3·50	0·90	5·29*	❶ > ❷	21·71
								❶ > ❸	23·24
Perceived susceptibility	2·77	1·28	2·80	1·58	3·13	1·40	0·60		
Perceived seriousness	3·13	1·38	2·83	1·41	3·16	1·59	0·46		
Perceived benefits	3·60	1·53	2·40	1·30	3·10	1·47	5·30*	❶ > ❷	33·33
Perceived barriers	3·13	1·47	2·86	1·63	3·20	1·39	0·41		
Behaviors	19·40	4·68	17·66	4·91	16·73	4·32	2·54		

*$p < 0{\cdot}05$.

Table 4 Cost-effect analysis among three groups

	Cost-effect = cost (NT)/(post post test score − pre-test score)		
	Exp. group 1	Exp. group 2	Control group
Knowledge	120·20 (167·09/1·39)	252·75 (141·54/0·56)	827·26 (124·09/0·15)
Perceived susceptibility	4177·25 (167·09/0·04)	2830·8 (141·54/0·05)	2481·8 (124·09/0·05)
Perceived seriousness	7595 (167·09/0·22)	4718 (141·54/0·03)	3102·25 (124·09/0·04)
Perceived benefits	355·51 (167·09/0·47)	1088·76 (141·54/0·13)	1772·71 (124·09/0·07)
Perceived barriers	2387 (167·09/0·07)	707·7 (141·54/0·2)	12409 (124·09/0·01)
Behaviors	29·99 (167·09/5·57)	48·80 (141·54/2·9)	41·78 (124·09/2·97)

Cost (NT dollar).

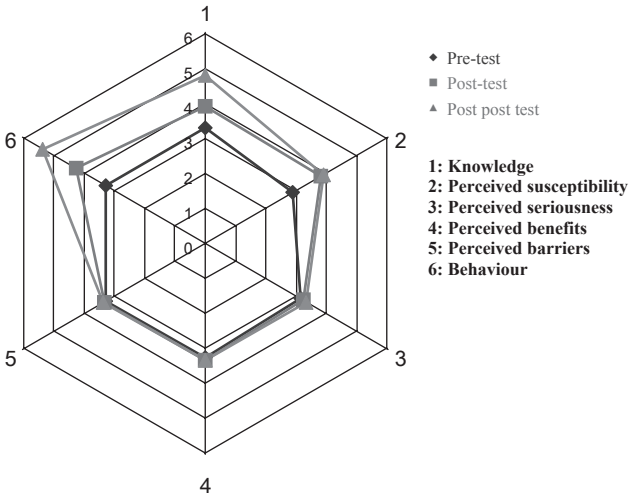

Figure 2 Results of radar chart of at risk female in experimental group one.

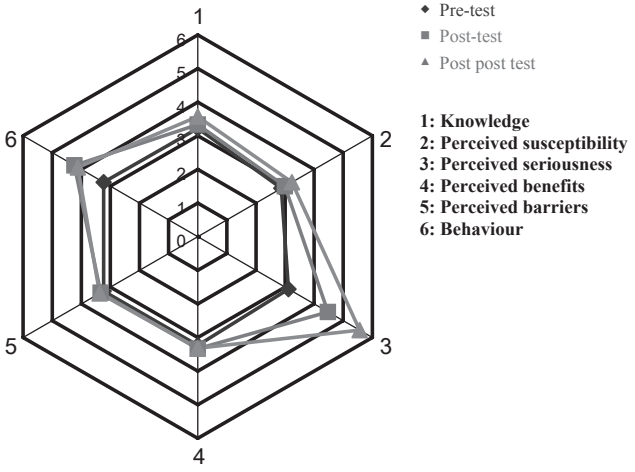

Figure 3 Results of radar chart of at risk female in experimental group two.

Moreover, with respect to woman beliefs towards osteoporosis in this study, women view osteoporosis as a serious disease that they will contract in their lifetime. Also, despite understanding that proper measures can reduce the incidence of osteoporosis, they feel that prevention action is difficult to adopt. This finding somewhat resembles the finding of Hurst and Wham (2007) that women did not believe that they would contract osteoporosis despite considering to be a serious disease; Hsieh *et al.* (2001) indicated although 89% of all women consider osteoporosis a serious disease, but only 29% of them felt that they would contract it; Chang *et al.* (2003) also made a similar observation. Thus, by undertaking different nursing measurements, this study provides personal nursing instructions to improve self-awareness and enhance

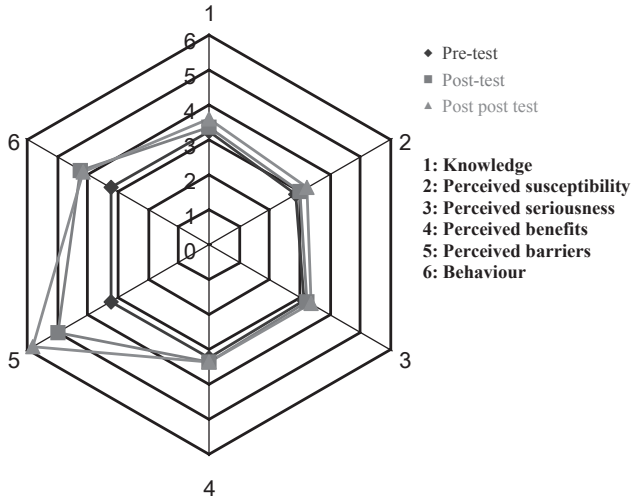

Figure 4 Results of radar chart of at risk female in control group.

the understanding of the disease severity. Moreover, the compliance behaviour analysis revealed that the behaviour intention of women undertaking osteoporosis prevention was only 50·0%, i.e., to the findings of Hsieh *et al.* (2001) that only 40% of all women were willing to take preventive action. Further analysis revealed that compliance behaviour of women in this study was statistically and positively correlated with osteoporosis knowledge, which is similar to the findings of Doheny *et al.* (2007) and Wallace (2002) in which osteoporosis prevention knowledge correlated with preventive behaviour. Thus, promoting knowledge of osteoporosis among women would help them to adopt preventive action, a finding which is a valuable reference for future research involving community nursing staff.

Determination of the accuracy of IOHRES

According to the Taiwan Bureau of Health Promotion, Department of Health (2005), a national health interview and drug abuse study involving 11 827 individuals above 35 years old found that the prevalence rate of individuals having 'self-reported osteoporosis by doctor's diagnosis' was 10·44%. Of which, the prevalence rate among men was 6·01%, while the prevalence rate among women reached as high as 14·91%, i.e., the risk among women was nearly threefold higher than men. Thus, if calculated by the prevalence rate of 14·91%, the PPV of this study is 0·35; the NPV is 0·95. However, if estimated by an increased prevalence rate of 20% among women, then the PPV increases to 0·43 while the NPV decreases to 0·92. Previous results suggest that this software is more appropriate in an area with a high prevalence rate of osteoporosis or in an age

level with a higher risk to screen the osteoporosis risk among women.

Additionally, the accuracy of the osteoporosis health risk appraisal system developed in this study is as high as 75%. However, in a survey involving medical prediction software, Liu (2003) developed a clinical medical diagnosis of coronary artery diseases based on use of artificial intelligence (AI) technology, in which the optimum diagnosis accuracy of the system is 95·6%. Lee (2003) examined the applicability of AI technology in human health management, which involved developing a chronic disease prevention strategy and deduction diagnosis system. The accuracy of diagnosing new cases of chronic diseases reached as high as 86%. More closely examining its database found that all was based on clinical blood samples and the biochemistry index, explaining why the accuracy of the proposed prediction software can exceed 85%. However, the health risk appraisal system developed in this study is based on a telephone interview that asks women to recall their life history. The obtained risk factors, knowledge, beliefs and behaviours related to osteoporosis were used to precede osteoporosis health risk evaluation. Additionally, owing to a lack of invasive data (e.g., blood index), it can not reflect the actual response and precise bone density of women. Therefore, the risk appraisal system developed in this study is more applicable to the real-life experiences of community-dwelling women and can provide an appropriate health risk evaluation.

Analysis of the effects of different nursing interventions

To understand the long-term effects of nursing measurements, this study undertook a post-post-test after 12 weeks of a pretest to understand the longitudinal effects on osteoporosis prevention knowledge, beliefs and behaviours in women. According to those results, women in experimental group 1 obtained a continuous and effective change in osteoporosis knowledge; comparative results of experimental group 2 and the control group achieved an improvement of 21·71% and 23·24%, respectively. This finding resembles that of Chang *et al.* (2007) and Sedlak *et al.* (2007). Therefore, in addition to personal nursing instruction, continuous awareness of providing self-prevention methods can encourage women to pay attention to valid osteoporosis-related information. Thus, according to our results, multiple strategies used by community nursing staff can encourage women to maintain relevant osteoporosis information.

Our study found that different nursing introducing measurements can not encourage the osteoporosis preventive behaviour of women. This finding resembles that of Chang *et al.* (2007) and Sedlak *et al.* (2007) indicated that personal behaviour can not be changed in a short time, long term and continuous monitoring is required. Our results further demonstrated that the knowledge and benefits score of experimental group 1 were higher than that in experimental group 2 after 12 weeks. Restated, combining multiple nursing introducing measurements can promote osteoporosis knowledge and benefits among women at risk, which is similar to the finding of Ma (2001), Zhu (2004), and Chang (2011).

Additionally, continuous monitoring of the effectiveness of a nursing intervention program after 12 weeks of intervention, especially for the cost-effectiveness factor in the knowledge scores, the experimental group scored higher than the experimental group 2 and control group did, in which the cost savings are up to 2·1–6·9 times. Meanwhile, cost-effectiveness analysis revealed that for the perceived efficacy of osteoporosis prevention, experimental group 1 had a high cost savings than experimental group 2 and control group did, in which the cost savings were up to 3·1–5·0 times. This study further demonstrated that the knowledge and perceived benefits of osteoporosis can be promote by individual nursing instruction and continuous reminding and the ability to obtain economical and effective results, which resembles the findings of Chang (2006) and Wen and Sheu (2005).

Repeat measurements analysis of three groups of women at risk of bone loss and osteoporosis in terms of knowledge, beliefs and behaviours

ANCOVA repeat measurements analysis revealed that women at risk of bone loss and osteoporosis only had statistically difference in knowledge, but not a statistical difference in belief and behaviour. Therefore, a radar chart was used to further analyse the knowledge, beliefs and behavioural intentions of each group of women at risk of osteopenia and osteoporosis.

Figure 2 revealed that osteoporosis knowledge and behaviour of experimental group 1 were most prominent than in the other two groups. This finding suggests that the osteoporosis knowledge and behaviour of women at risk had received continuous promotion by different nursing programs. According to Fig. 3, after providing a nursing instruction booklet, women at risk in experimental group 1 perceived osteoporosis as more seriousness than those in the other two groups did. This finding suggests that via a nursing instruction booklet, women could be reminded that osteoporosis is a serious disease. Finally, according to Fig. 4, women at risk in the control group did not think that they were susceptible to the disease. Moreover, they also felt

difficulty in understanding osteoporosis prevention and did not understand how to overcome the obstacles they encountered. This finding suggests that women at risk who did not receive any nursing instruction lacked alertness towards a susceptibility risk of osteoporosis; they also felt difficulty in self-care prevention of osteoporosis. According to previous studies, an effective osteoporosis introduction program can provide valid evidence based on a comprehensive design and control of longitudinal study (Huang 2003, Chang 2011). Previous results suggest that the strategic application of multiple nursing instructions can promote osteoporosis prevention knowledge in women at high risk and can yield better prevention results. This observation is similar to that found in many other studies (Chang 2003, Cook *et al.* 2007, Kanis *et al.* 2007).

Conclusion

By utilising the multidisciplinary expertise of nursing, medical and information technology professionals, this study develops osteoporosis intelligent health risk appraisal approach with practical value. This innovative risk appraisal method is applicable for health risk evaluation in different diseases in the future. This scheme provides community residents with a highly reliable, valid, practical, convenient and economic self-health management model. Additionally, this study integrates nursing program design, in which the results of the empirical study can be used by community nursing staff. This study has developed an osteoporosis risk appraisal procedure, results of which have high prediction accuracy. In the future, the software should be placed online. Moreover, the designed Web page can be used in the community for long-distance home care.

Limitations

Despite its contributions, this study has certain limitations. Given that this study adopted the purposive sampling method to select the study subjects, the estimated results may be inapplicable to estimate the total accessible population. In the future, a sample chosen based on a large-scale random sampling method would be favourable to an effective inference. This study adopted the longitudinal research method, in which the tracing time was 12 weeks. This method could not completely understand the long-term effects of introducing nursing measurements, especially in terms of the behaviour on how to carry out osteoporosis prevention. Therefore, a future study should extend the observation time to understand the longitudinal effects. The risk prediction accuracy of this osteoporosis health risk appraisal system in the study was 75%. Therefore, the results may be underestimated when women undergo osteoporosis risk evaluation. Thus, for those women not diagnosed as at risk to osteoporosis, osteoporosis-related prevention and health care information must still be provided. Additionally, with the respect to the software developed in this study, efforts should be devoted to developing software with a higher accuracy to further benefit women in the early diagnosis of osteoporosis risk so that an effective preventive strategy can be adopted.

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Contributions

Study design: SFC, CMC, RSY, RJY; data collection and analysis: SFC, CYH and manuscript preparation: SFC.

Conflict of interest

None.

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