WEB-BASED SYSTEM FOR ASSESSING RISK FACTORS FOR FALLS IN COMMUNITY-DWELLING ELDERLY PEOPLE USING THE ANALYTIC HIERARCHY PROCESS

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ABSTRACT

Falls occur frequently among older people and represent the most common cause of injury-related morbidity and mortality in later life. Preventing falls is an important way to reduce injuries, hospitalizations, and injury-related morbidity and mortality among older

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This project of research, and so far the collaboration between the University of Sheffield and Napoli, was in part supported by academic award for mobility of Ph.D. students from University Federico II. An earlier version of this paper was given at the ISAHP 2009 conference (Pecchia et al., 2009).

people. The research literature has identified hundreds of risk factors for falls among elderly people. Prioritizing risk factors for falls is useful for designing effective and efficacious prevention programs. The aim of this study was to use the Analytic Hierarchy Process to develop a hierarchy of risk factors for falls based on the knowledge and experience of experts working in this field. We designed and developed a web portal for participants to submit responses to electronic questionnaires in order to reach the highest number of respondents quickly and to reduce errors in responding. We contacted the person responsible for the Falls sections of four scientific societies. Finally, we propose a correction method to modify respondents' relative importance on based on the coherence of their responses, in order not to exclude experts who had submitted the questionnaire twice.

Keywords: AHP falls in elderly people, web service

http://dx.doi.org/10.13033/ijahp.v2i2.61

1. Introduction

Evidence-based medicine and health care is becoming increasingly important for assessing the effectiveness of a new health care program. Nonetheless, in order to maximize the effectiveness, health care professionals (HCPs) need to incorporate empirical and experiential evidence with physiological and biomedical principles, considering also the individual patient's condition — whom they may know personally — their professional values, and features of the system (Tonelli, 2001). The relative weight given to each of these areas is not predetermined, but varies according to specific patient's condition and the HCPs' experience. Therefore, it is important to understand the perspectives of HCPs on how they balance factors affecting decision-making and care, and whether there is any consistency among them. Everyday practice, in fact, often differs from evidence-based procedures reported through guidelines.

Our study aims to investigate the opinion of a wide number of professional caregivers, with different specializations and experiences, in facing the complex and multi-factorial problem of preventing falls in home-dwelling elderly people. We used the Analytic Hierarchy Process (AHP) (Saaty, 1980), to develop a hierarchy of risk factors for falls based on the knowledge and experience of experts working in this field. Another reason leading us to investigate experts' opinion was that not all falls cause injuries, and for this reason, since we were interested in prioritizing risk factors for any kind of falls, we chose not to base our hierarchy on hospital reports.

Falls occur frequently among older people and represent the most common cause of injury-related morbidity and mortality in later life (King and Tinetti, 1995; Nevitt and Cummings, 1989). The annual incidence of falls among older people is estimated to be between 15% and 40% in community-dwelling people aged 65 and over. The consequences of falls range from psychological harm (Parry and Steen, 1982), physical injuries (Lord and Sherrington, 2007), and hospitalization, to death. Falls can also negatively affect well-being, mobility, autonomy, and overall quality of life. Preventing falls is therefore an important way to reduce injuries, hospitalizations, and injury-related morbidity and mortality among older people (Oakley, 1996). Identifying and prioritizing risk factors for falls is useful for designing effective and efficacious prevention programs.

The research literature has identified hundreds of risk factors for falls among elderly people (Gillespie 2000), and it is well established that falls risk in old age is complex and multi-factorial. Moreover, it has been shown that reducing risk factors (Tinetti, 1996) and developing multi-factorial interventions (Tinetti, 1994) are important strategies for reducing the frequency of falls in home-dwelling elderly people. However, we did not find any reports in the research literature of the views of health care professionals on the relative importance of these risk factors. The aim of our study was to examine the views of health care professionals on the relative importance of risk factors for falls in community-dwelling older people.

In order to reach a wider number of experts, we designed and developed a web-based system for respondents to submit questionnaires and to analyze the results. The respondents could not discuss their opinion among themselves to reach a consensus, as we were interested in investigating differences in the opinions of professionals. Moreover, we chose not to submit the same questionnaire to the same respondents twice, since this was time consuming for them, as clinicians, and would have reduced the responses we received. This led us to adapt the AHP methods to our specific needs, as is discussed further in this paper. Although this represents a limitation of the study, this is nonetheless only the first step in our research and further research could utilize a focus group approach with fewer numbers of experts to reach consensus using a more iterative approach.

The aim of this paper is to describe the system we developed and, because we modified the AHP method slightly to adapt it to our specific needs, we present and discuss the effects of these adaptations. In order to demonstrate the effectiveness of the web application and the effect of the proposed adaptations, preliminary results from this research are presented.

2. Method

The method used to prioritize the risk factors is an application of the Analytic Hierarchy Process (AHP), implemented via the World Wide Web. We adopted AHP as an analytic decision-making method to understand the risk of falls in older people, a problem that is complex, multi-factorial, and multi-dimensional, and therefore suited to this approach (Saaty, 2005).

2.1 Hierarchy of risk factors

Using the research literature, we identified a range of risk factors for falls, and designed a tree by grouping them into categories (that is, general and clinical) and sub categories (that is, physical, mental, socio-environmental, physical health, drugs and medical conditions). We then developed and piloted a questionnaire asking experts to compare pairs of categories, sub-categories, and factors. The tree of factors with their relative priority weights lead us to the hierarchy. This hierarchic approach allows the construction of a consistent step-by-step framework for decision-making.

2.2 Questionnaires

In order to reach the highest number of respondents, we designed an electronic questionnaire, located at: http://hosting.vaisuinternet.it/, and a web-based service (Pecchia, 2008), to analyze the answers remotely. For each pair of category of risk factors (R_i, R_j) the respondent was asked the following question: "in your opinion is R_i, compared to R_j: much more important, moderately more important, equally important, moderately less important, much less important." We posed similar questions to compare the categories of risk factors. Several numerical scales have been proposed, apart from the Saaty fundamental scale, such as the geometrical scale (Finan, 1999, Ji, 2003, Lootsma, 1993) and the Salo-Hamalainen scale (Salo, 1997). The Saaty scale and the geometrical scale are the most commonly used ones. The Saaty scale has been supported by Saaty's empirical evidence, but, as described above, it is not a transitive scale. As demonstrated by Dong (2008) et al., the geometrical scale is thought to be transitive; however, as Saaty (1994) points out, it is difficult to determine the parameters of the geometrical scale. Therefore, in accordance with the natural scale of Saaty (Table 1), we gave a numerical value to each judgment:

Table 1
Saaty Fundamental Scale

Judgments	Score
much more important	5
moderately more important	3
equally important	1
moderately less important	-3
much less important	-5

Piloting the questionnaire, as described below, we decided to use 5 ("much more important") as the maximum magnitude, since the first group of respondents in the pilot appeared to be unclear about using the larger scale, because respondents reported that, in their opinion, there were not factors dominating the others greater than "much more". The negative signs were used in order to incorporate the responses into a single question, which factor was dominant and by how much. The negative numbers (a_{ij}) were then transformed, via a web service, in its positive reciprocal (a_{ij}^*), using the transformation in equation 1:

$$a_{ij}^* = -\frac{1}{a_{ij}} \qquad (1)$$

This relation means that, mathematically, if R_i is "moderately less important" than R_j ($a_{ij} = -5$), then R_j should be much more important than R_i ($a_{ji} = 5$), therefore the reciprocity of the judgments matrix implies $a_{ij} = 1/5$. Moreover, respondents were permitted to use intermediate judgments (as shown in
Figure 4), scored with even numbers (positive and negative), to express further insights, or if they could not decide between adjacent categories.

2.3 Judgments matrixes

With the scores provided by each respondent, the web service automatically evaluated the judgment matrix A. It has been shown that, if the judgments are consistent (see next section for details), the normalized eigenvector of this matrix expresses the relative importance of each risk factor. We iterated this step for each category of risk factor. Finally, the same algorithm allows the relative importance of each category of risk factors to be assessed.

As explained in the following paragraphs, we chose not to compute the average judgment matrix by calculating the geometrical mean between each element. Instead, we evaluated a matrix, and so far a vector of global priorities, for each respondent. This allowed us to present the spread of the opinions of the respondents, reporting a range of global priority weights for each factor. Then we computed the algebraic mean of these weightings with the relative importance of each respondent, as stated below.

2.4 Consistency

From each matrix it is possible to estimate the consistency of the responses from each respondent, in order to test the *transitivity of judgments*, which is a fundamental hypothesis in each decision making method. Obviously, a perfect coherence is difficult to achieve for complex judgments. Nevertheless, it is always important to assess the degree of coherence of respondents because a high level of inconsistency by individuals can lead to a low level of *consistency* in the decision framework.

The AHP allows the consistency of any questionnaire responses to be measured by posing some redundant questions (Saaty, 2005b, Saaty 1996). For instance, to compare the three elements, A, B, and C, the respondent is asked to perform the comparison of B with C (a_{BC}), which could be deduced by the pair comparisons A-B (a_{AB}) and A-C (a_{AC}).The answer is then compared with the deduced judgment and the difference represents the degree of inconsistency. If the two judgments are not perfectly consistent, there will be an error, which can be quantified as:

$$error_{BC} = a_{BC} - \frac{a_{AC}}{a_{AB}} \qquad (2)$$

This error is zero if the judgments are perfectly consistent. Mathematically, the consistency of each response is measured with the error generalized defined as:

$$error_{ij} = a_{ij} - a_{1j} * a_{i1} \qquad (3)$$

Nevertheless, inconsistency is often due to distractions or loss of interest by the respondent and not to a global inconsistency in the respondent's opinion. This is particularly true in a web based response system. For this reason, when responses are inconsistent, the questionnaire should be re-submitted to the respondent. This strategy is possible when the respondent can meet with the researchers to discuss and settle inconsistencies in responses; however, this was not possible in this study, the exception to this being the piloting.

At this point, we chose a threshold error and excluded respondents with a higher level of inconsistency. Then we used the inverse of the consistency index to correct the relative importance of each respondent before pooling the data. This method of pooling techniques is that used in meta-analysis (Sutton et al., 2000)

Finally, we modeled the *error* as an accuracy-error, which is zero when the framework is completely consistent. An increasing error means a progressive loss of consistency individually and overall. This error is then propagated until the final index of relative importance affecting its precision is estimated. For instance, if a respondent judges A>B and B>C, she/he should judge A>>C. A direct answer of A>C or A>>>C, is not perfectly consistent, but it is certainly more consistent than A<C or A=C. The AHP defines a method to assess the degree of inconsistency. We adopted this technique to correct the relative importance of respondents in order to pool the final data as described above. Moreover, we used this error to define the interval of precision of each relative weight.

2.5 Assessment of relative importance

As stated above, after excluding inconsistent respondents and comparing the risk factors, we calculated the Relative Importance index (RI) within each sub-category (termed "intra-categorical weights" or "Local Weights", LW). From the pair-wise comparisons of categories and sub-categories, we estimated the relative importance of each of them ("inter-categorical weights", ICW). Finally, by using both weights, we estimated the global relative importance of each risk factor ("global weights", GW). All those weights are affected by the error described above, and have to be reported with an imprecision of less than, or equal to, the threshold-error.

2.6 The web system

To reach a wider range of respondents, we designed and developed a web portal for completion of the questionnaires, and a web service for processing the data, analyzing the results and pooling.

The whole system, follows the so-called "Three Tier Layer" architecture, and is organized in three areas (see Figure 1): the "Client Area" that acts as presentation tier, the "Server Area" as business tier and data tier and the "Web Service Area" as a pure business tier level. Each of these areas is independent of the others and can operate with other information systems using common standards. In summary, the "Client Area" aims to collect data and presents an elaboration of the results; the "Server Area" to manage, to store and to retrieve data; the "Web Service Area" to process raw data and transform it from the judgment matrix to relative importance weights. Moreover, in this area, a web service analyzes data regarding respondent experience and, following the system described above, executes the data pooling.

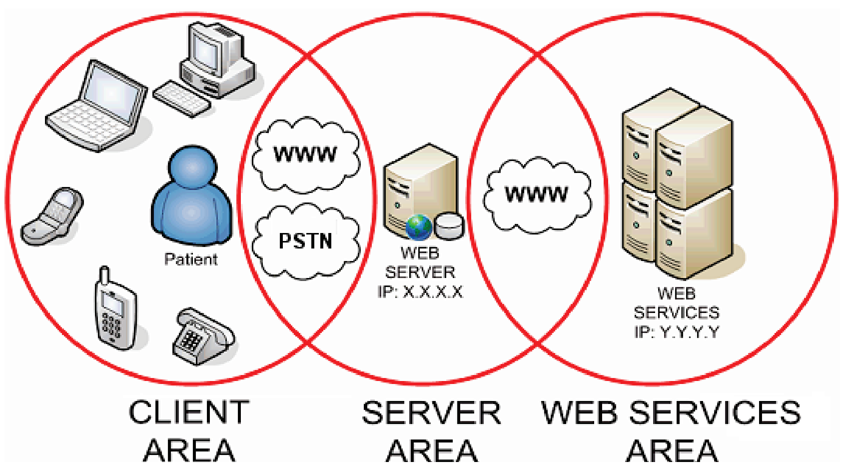

Figure 1 Three "Areas" of the web-based system: Client, Server and Web Services

2.7 Data pooling

We pooled global priorities using a weighted average of the judgment of each respondent. We weighted each respondent (W_r) based on her/his experience, taking into account the following information about respondents: years since specialization, level of education, area of work. These three features were considered equally important, while Table 2 presents the weights assigned to each element of each feature. This assignment was chosen according to the hierarchy proposed by Saaty (Saaty, 2010). The "Relative Importance Weight" is defined as $W_r/\min(W_r)$, so that it is clear that a Ph.D. is considered about 12 times more important than a professional qualification. Although this normalization is more sensible to variation in case new features are inserted, it is much easier to communicate to respondents and decision-makers not skilled in mathematical methods, which was the priority in this study.

Table 2
Weighting assigned according to time since qualifying, highest educational qualification and area of work

Feature	Weight (W_r)	Relative Importance Weight
Years since qualification		
>15	0.61	15.3
6-15	0.25	6.3
3-6	0.10	2.5
1-2	0.04	1.0
Education		
Ph.D., MD, or equivalent	0.59	11.8
MSc or equivalent	0.25	5.0
BCS or equivalent	0.11	2.2
Professional Qualification	0.05	1.0
Area of Work		
Falls health services/studies	0.57	4.1
Elderly health services/studies	0.29	2.1
Other	0.14	1.0

2.8 Correction of respondents relative importance in case of not perfect coherence

As described above, we submitted the questionnaires to the respondents, who were not in a single location. At this point, we could not ask them to resolve divergent judgments in order to achieve a consensus. Moreover, we preferred not to exclude respondents neither to ask them to complete the questions again, because of the limited time they had available. For these reasons we introduced a correction method in order to accept respondents with a CR over the suggested threshold of 0.1. Then we used the exceeding ΔCR to correct the relative importance weight (W_r^*) of respondents using the formula (3).

$$\begin{cases} \Delta CR = CR - 0.1 \\ W_r^* = W_r & if \quad \Delta CR \le 0 \\ W_r^* = W_r * (1 - 10 * \Delta CR) & if \quad \Delta CR \in \left]0;0.1\right] \end{cases} \tag{4}$$

We adopted a threshold of 0.1 because the maximum size of elements compared in one category is seven (Saaty, 2003, Saaty, 2010). Nonetheless, this threshold could in future be related to the size of the matrix.

3. Results and Discussion

3.1 Hierarchy of Risk Factors

From the research literature, we individuated a set of 39 risk factors (Tinetti, 1996, Tinetti. 1994, Gillespie, 2000), which was reduced to 35 during the pilot study, based on feedback from the respondents. Five factors were excluded ("falls in the previous 12 months," "capacity to describe causes of previous fall's," "loss of control," "structural diseases," "cardiovascular medicine") because they were considered confusing or repetitive with respect to other factors and a two additional factors were introduced ("poor self rated health" and "previous syncope") at the suggestion of those participating in the pilot study. We organized the 35 factors into categories and sub-categories by developing a tree. In the research literature, various studies have investigated risk factors for falls. However, few authors have proposed classifications to categorize risk factors (Panel of Falls Prevention, 2001) and none is based on the opinion of experts from different specializations. The tree we designed is shown in figure 2.

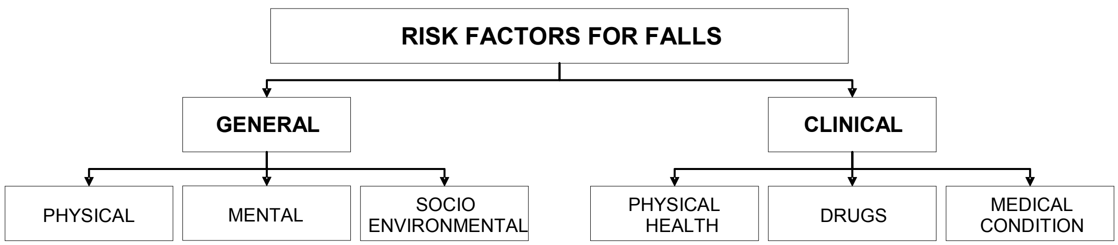

Figure 2 Tree of Risk Factors

We considered general risk factors (Table 3) to be those that might concern any older person (including healthy older people), and which include environmental factors.

Table 3
General risk factors organized according to each sub-category

Physical	**Mental**	**Socio-environmental**
high body mass index (bmi)	fear of falls	need help toileting
loss of weight	depression	low family support
poor joint flexibility	early stage dementia	low social engagement
low walking speed	loss of balance	low social service support
low muscular strength	low cognitive perception	need to use stairs/steps in home
low level of physical activity	perceived risk of falls	
	poor self rated health	

This category was further split into three sub-categories: *physical,* which includes those factors associated with an individual's stature and capacity; *mental*, which includes psychological factors associated with aging; *socio-environmental*, which includes factors related to the living arrangements of the person.

Clinical risk factors concern frail older people with various health problems (Table 4). This group includes three sub-categories called: *physical health factors*, which are, in different proportions present in healthy, as well as in pathological subjects; *drugs*, which embrace different medications; *medical conditions*, which include diseases typically affecting elderly people.

Table 4
Clinical risk factors organized according to each sub-category

Physical health	Drugs	Medical condition
visual problems	anti-depressives	postural hypotension
continence problems	anti-psychotics	nervous system disease
dizziness	beta-blockers	musculoskeletal disease
mobility aids	diuretics	stroke
sleeping problems	sedatives	polypharmacy
		previous syncope
		taking any prescribed drugs

3.2 Questionnaires

As described above, we organized the 35 risk factors into 2 categories and six subcategories. At this point, we needed seven questionnaires, six of which assessed local weights and one to assess category weights. We first used a paper-based questionnaire in order to pilot it in-lab. We then designed and implemented a web page for each questionnaire to reach the highest number of respondents as described below. The time taken to complete the paper version was almost double that for the web-based version: the mean time to complete the electronic questionnaires was 20 (±12) minutes for the respondents involved in the technical pilot, to 27(±14) minutes for the recruited experts, compared to a mean time of 56(±16) minutes for the paper version. Additionally, we encountered several errors in the completed paper versions, due perhaps to the limited experience of the respondents with such a specific layout, even though we provided a detailed explanation at the start of each questionnaire, including full examples as shown in Figure 3.

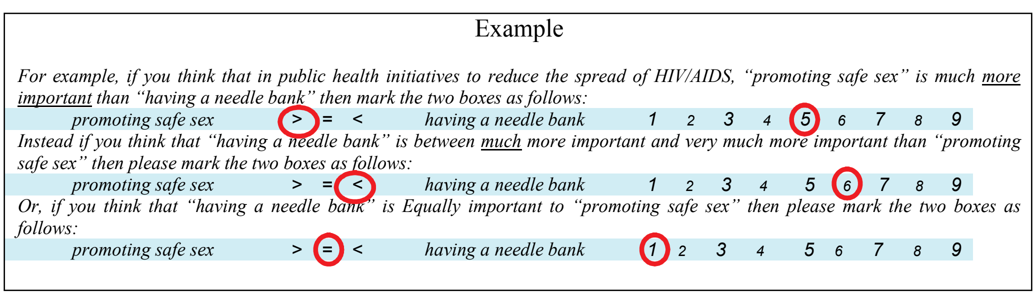

Figure 3 Example provided during the piloting of the paper-version of the questionnaire

In the electronic version no compilation errors were possible due to the use of "combobox" objects (Figure 4), which allows only a natural scale to be used instead of "sign and magnitude" to express pairwise judgments.

Figure 4 Combobox used to demonstrate responses.

In addition, we decided to randomize the order of pairwise comparisons to avoid automatic responses from respondents who might get tired of completing a long questionnaire. Moreover, we ensured that we had the same number of recurrences of each risk factor to the left and to the right of the comparison. We did this in order to reduce possible biases due to the tendency of inattentive respondents to correlate the importance of factors to their usual reading. Figure 5 and Figure 6 show the same questions implemented in the paper version and in the electronic one respectively.

***Section 3.2,* Clinical risk factors. Questionnaire 4: Physical Health risk factors**

Indicate which you think is the more important physical health risk factor for falls in older people.

visual problems	> = <	ear problems	1	2	3	4	5	6	7	8	9
continence problems	> = <	physical aids	1	2	3	4	5	6	7	8	9
physical aids	> = <	ear problems	1	2	3	4	5	6	7	8	9
sleeping problems	> = <	visual problems	1	2	3	4	5	6	7	8	9
ear problems	> = <	continence problems	1	2	3	4	5	6	7	8	9
visual problems	> = <	physical aids	1	2	3	4	5	6	7	8	9
physical aids	> = <	sleeping problems	1	2	3	4	5	6	7	8	9
sleeping problems	> = <	continence problems	1	2	3	4	5	6	7	8	9
ear problems	> = <	sleeping problems	1	2	3	4	5	6	7	8	9
continence problems	> = <	visual problems	1	2	3	4	5	6	7	8	9

Figure 5 Paper version of questionnaire

One set of questions from the paper version is shown in Figure 5. We randomized the order of pair wise comparisons and ensured that each factor was twice on the left and twice on the right.

Figure 6 Electronic version of questionnaire

The same set of questions in Figure 5 is shown as they are implemented in the electronic version in Figure 6. The drop-down boxes provide options for the respondents to select the appropriate response category.

Finally, the elaboration of responses performed via the web services, as described further in the paper, allowed the post-elaboration time and the risk of error due to manual transcription to be reduced; this was especially important with this number of respondents.

It is well known that the wording of the questions, the order in which they are asked, and the number and form of alternative answers offered can influence the results of surveys. This is particularly important when the questionnaire is submitted via the web with no direct feedback from the responders. For this reason, we tried to reduce wording bias by adopting some forethought. As is evident in Figures 5 and 6, in each section of the questionnaire all the RFs appear the same number of times on the right and on the left, so that the respondent could be not influenced by the impression of comparing the RF with the “other.” Also the order of the questions is random and neither the same RF appears in two consecutive questions, so that the respondent could be not influenced because of comparing a RF in sequence with all the remaining RFs. All the words used in the questionnaire are technical and selected from literature, so that their meanings and connotations could be clear and familiar to respondents. In order to minimize non-response bias, we recruited experts through the “Falls” section of national scientific societies of geriatricians (British Geriatrics Society) and physiotherapists (AGILE). We have no reason to believe that those specialists who did not respond are any different from the ones who did respond. Therefore, we feel it is reasonable to assume that the final results are minimally affected by non-response bias related to the respondents' professional background.

3.3 Respondents and execution of the study

Research ethics approval was obtained for this study from the University of Sheffield. A technical pilot study involving 32 respondents was first performed in our labs to define the editorial model while trying to minimize the risk of errors. A scientific pilot study involving a group of nine experts, with different backgrounds and specializations, then completed the questionnaires independently. All nine respondents had working experience in the field of falls in the care of elderly people. Four **physicians** (comprising a ***consultant geriatrician*** with 11 years' experience, a ***general practitioners/family doctors*** with 28 years' experience, a MD who specialized as a ***gerontologist*** with 28 years' experience, and a ***geriatrician*** with 22), four **physiotherapists** (with 10, 12, 13 and 13 years' experience) and one **professor of physiotherapy** comprised the group. An invitation letter, containing a link to the questionnaire, was sent by email via the moderator of the email distribution list for the British Geriatrics Society (BGS) Falls special interest group, the AGILA Chartered Society of Physiotherapy working with older people, and to a program of work focused on falls preventions called the "Preventing Falls Program." The link contained a "get" variable to track the association of the respondent, so we know that, from the 196 final respondents who visited the web questionnaire, 163 were experts from these groups. Of these, 68 (41.7%) completed the questionnaires. Table 5 gives details about all respondent background.

Table 5
Number of respondents during piloting and the final group of "consistent" respondents.

	Technical Piloting	**Scientific Piloting**	**Final respondent experts**
University	31	1	2
Physicians	1	4	12
Physiotherapists	-	4	44
Nurses	-	-	10
Total	32	9	68

From the group of "final respondent experts" and the "scientific piloting group", 29% worked in "falls services" and 42% worked within "general elderly care services". 16% reported having an MSc and 8% reported having a Ph.D. or MD. The mean number of "years since qualification" was 18.9 (±10.56).

Of the 68 final respondents, 10 (14.7%) completed the questionnaire ***consistently*** with a CR <0.1, as suggested by Saaty, in all subcategories. Moreover 24 (35.3%) exceeded the recommended threshold level in just one section out of seven, with a CR mean of 0.14(±0.03). As explained above, because we preferred neither to exclude respondents nor to ask them to answer again, we used a correction method for the respondents who answered with a $CR \in (0.1;0.2)$. We increased the CR level, using the ΔCR to correct the relative importance of respondents as described in formula (3). We also included respondents with a CR≤0.2, (n=37; 54.5%) with such a CR in all seven sections of the questionnaires, and 62 (91.2%) if we include the ones that achieved CR in six of the seven sections of the questionnaires.

3.4 The web system

The aim of the web-based system was to reach as wide a range of respondents as possible. We designed the complete system using .NET web technologies, particularly so that we could easily implement controls to avoid compilation errors. For example, the system did not allow a respondent to proceed to the following section of the questionnaire if they had not answered all of the questions in the current section.

Figure 7 summarizes the architecture of the implemented platform and the logic of the system, which follows the three-tier level model outlined in Figure 1.

First, information about the respondent is requested. The system uses this information to calculate the weighting for the respondent. This weighting is further corrected (reduced) if the respondent's CR is between 0.1 and 0.2, using formula 3 presented above.

The respondent was then asked to prioritize risk factors within each sub-class (first the general risk factors followed by the clinical ones). Finally, she/he is asked to prioritize each sub-class and class. The system uses the responses to compose the priority matrices, from which it calculates relative priority weights and CR. If the CR is greater than the threshold of 0.2 in at least one matrix, the respondent is excluded from the final pooling. If the CR is between 0.1 and 0.2 in at least one matrix, the respondent's weighting is lowered according to formula 4. By weighting the priority of risk factors according to the relative importance of the respondent, the system computes and stores the Global Weights of each factor.

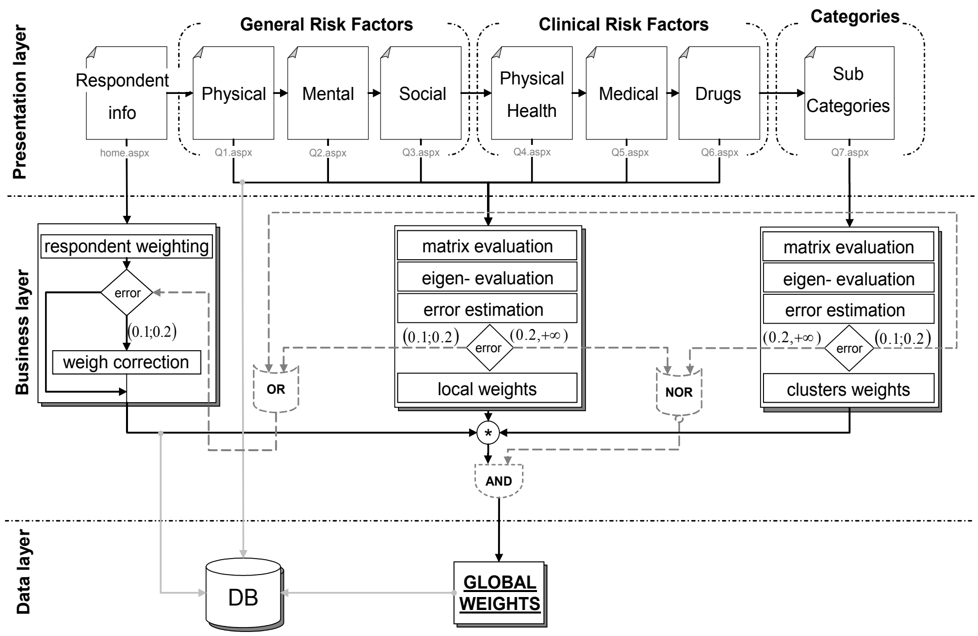

Figure 7 Web system architecture and service logic

3.5 Data Pooling

As discussed in the previous paragraphs, to pool the results obtained from different experts it is important to weight each feature of the respondent. The adopted weighting system is summarized in Table 2. We assumed that the three features could be considered to be of equally importance.

3.6 Fully coherent respondents

The results from the 10 respondents with a CR <0.1 in each matrix are presented in Table 6. In this table for each sub-category we reported: its parent category (see Figure 2); the mean among respondents of the relative importance normalized using the distributive mode; the range among respondents of the relative importance normalized using the distributive mode; its global weight (GW), which is the mean value among respondents of the relative importance of the sub-category, after weighting each respondent with the scoring system introduced in section 2.7; its relative importance weight (RIW), which is the GW normalized with the minimum the GWs among all the sub-categories [GW/min(GW)].

Table 6
Global weights of sub-categories of Risk Factors

Sub-Category	Category	Mean (%)	Range (%)	GW (%)	RIW
Mental	General	19.1	12-26	20.2	**1.5**
Physical	General	19.1	12-26	20.2	**1.5**
Physical Health	Clinical	16.4	11-22	15.5	**1.2**
Drugs	Clinical	16.2	10-23	15.3	**1.2**
Medical	Clinical	13.7	7-21	13.1	**1.0**
Socio-environmental	General	15.6	10-21	15.6	**1.2**

GW: Global Weight; **RIW**: Relative Importance Weight.

Table 6 shows that, for all the sub-categories, a score (the "inter-categorical weights") was evaluated for each respondent and then mediated (Mean) among all respondents. These values were then weighted with the relative importance of each respondent to obtain the Global Weight (GW) of each sub-category. The Relative Importance Weight (RIW) was estimated by dividing the GWs for the minimum sub-category, which is "clinical-medical subcategories" in this case. The RIW reflects how much, in the opinion of respondents, each sub-category is more important than the less important one. Although this normalization is less stable than is ideal in case one element in the hierarchy is changed, its results are easier to communicate to physicians. Finally, the range gives an indication of the data dispersion, which reflects the differences in the opinions of the respondents. These differences are also due to the general nature of the questions asked in this study; for example, if the questions were more focused on a particular case (for example, a patient suffering from specific condition, or using a more specific definition of a fall), it is possible that the respondents' opinions may have been less diverse. In fact, different groups of community-dwelling older people could have relatively different risk factors for falls. Nonetheless, the design of the questionnaire was done in such way because we were interested in any kind of falls. Furthermore, measure divergence among the respondents' opinions using AHP is a primary outcome of the study.

Table 7
Risk Factors

Risk Factor	**Category**	**Sub-Category**	**Mean (%)**	**Range (%)**	**GW (%)**	**RIW**
low muscular strength	general	physical	1.77	1.00-2.54	1.89	5.9
low level of physical activity	general	physical	1.61	0.93-2.29	1.72	5.3
loss of balance	general	mental	1.53	0.70-2.37	1.62	5.0
need help toileting	general	socio-environmental	1.56	0.67-2.46	1.59	4.9
fear of falls	general	mental	1.34	0.55-2.13	1.40	4.3
low walking speed	general	physical	1.03	0.27-1.78	1.13	3.5
poor joint flexibility	general	physical	1.12	0.75-1.49	1.12	3.5
use of sedatives	clinical	drugs	1.11	0.57-1.66	1.10	3.4
use of antipsychotics	clinical	drugs	1.07	0.58-1.57	1.08	3.3
early stage dementia	general	mental	0.96	0.38-1.53	1.07	3.3
use of anti-depressives	clinical	drugs	1.07	0.50-1.64	1.06	3.3
low cognitive perception	general	mental	0.97	0.62-1.33	1.03	3.2
dizziness	clinical	health physical	1.09	0.57-1.61	1.01	3.1
perceived risk of falls	general	mental	0.96	0.32-1.60	1.01	3.1
visual problems	clinical	health physical	1.06	0.59-1.53	1.00	3.1

Table 7 presents the relative importance of the first 15 individual risk factors. We evaluated the same synthetic parameters described above. RIW expresses the relative importance of each Risk Factor normalized to the least important factor ("low social services support").

The range shown in the previous tables is too high to identify clearly the classification between each consecutive risk factor. This may also be due to the high number of risk factors. Nonetheless, it is clearly discernible that there is consensus that some factors are much more important than others. An additional investigation could focus on these factors in order to provide a classification that is more selective.

3.7 Correction of respondents' relative importance in case of not perfect coherence

By applying the correction introduced above, we included 62 respondents obtaining the following results for the sub categories, as shown in Tables 8 and 9.

Table 8
Global weights of sub-categories of Risk Factors

Sub Category	Category	Mean (%)	Range (%)	GW (%)	RIW
Mental	General	22.6	13-32	23.1	**1.8**
Physical	General	18.0	11-25	18.3	**1.4**
Physical Health	Clinical	18.0	11-26	16.7	**1.3**
Drugs	Clinical	16.1	11-22	15.5	**1.2**
Medical	Clinical	13.2	7-20	13.6	**1.1**
Socio-environmental	General	12.0	7-17	12.8	**1.0**

Comparing Table 9 with Table 7 demonstrates that the ranks of classified categories of RFs do not change much with the exception of "Socio-environmental". In fact, the first five categories are significantly correlated with a Spearman's rank correlation coefficient of 97% ($p<0.05$). Nevertheless, the GWs of consecutive categories are too close, in comparison to the wide ranges observed (third columns in Table 7 and 9), which reflect divergence in the opinion of the respondents. Divergence among the respondents' opinions is a primary outcome of the study, which was revealed by the AHP.

Table 9
First 15 risk factors with error corrections

Risk Factor	Category	Sub-Category	Mean (%)	Range (%)	GW (%)	RIW
loss of balance	general	mental	1.90	0.61-3.20	2.10	5.9
fear of falls	general	mental	1.79	0.82-2.76	1.75	4.9
low muscular strength	general	physical	1.65	0.86-2.44	1.68	4.7
low level of physical activity	general	physical	1.33	0.68-1.98	1.40	3.9
need help toileting	general	socio-environmental	1.17	0.53-1.82	1.28	3.6
Sedatives	clinical	drugs	1.32	0.84-1.80	1.23	3.4
perceived risk of falls	general	mental	1.22	0.56-1.88	1.19	3.3
dizziness	clinical	health physical	1.31	0.43-2.20	1.16	3.2
visual problems	clinical	health physical	1.31	0.56-2.06	1.15	3.2
antipsychotics	clinical	drugs	1.06	0.61-1.51	1.09	3.0
poor joint flexibility	general	physical	1.14	0.44-1.83	1.06	3.0
early stage dementia	general	mental	1.07	0.24-1.90	1.06	3.0
low cognitive perception	general	mental	0.99	0.55-1.43	1.02	2.8
low walking speed	general	physical	0.94	0.30-1.58	1.00	2.8
postural hypotension	clinical	medical	0.98	0.39-1.57	0.99	2.8

In addition, the results on Risk factors prioritization do not change substantially, when comparing Table 9 with Table 7. Among the first 15 risk factors, 14 are the same in both groups of respondents. The first five are almost in the same order. Nonetheless, the difference between the RIWs of consecutive factors is minor, and comparable, to the range. This leads us to conclude that a detailed classification of all the factors could be not fully statistically significant, due to the divergence in the opinions of respondents.

Moreover, both groups of respondent were in agreement in classifying drugs "high bmi" and "Taking any prescribed drugs" as the two factors with the lowest priority for falls risk in elderly people, and the final ten factors are the same.

3.8 Comparison with previous studies

A limited number of studies (Rubenstein, 1996, Rubenstein, 2006, Masud 2001) have proposed a classification of the most likely causes of falls in elderly people, based on hospital records. They based their classification on the mean percentage of a cause's prevalence, calculated from the 3,628 falls reported across 12 studies. These studies considered only few of the RFs that we included in our hierarchy. Among these, particularly important causes of falls reported were (in decreasing order of importance): (1) gait/balance disorders or weakness (prevalence 17%, range among studies 4-39%); (2) dizziness/vertigo (13%, 0-30%); (3) confusion (5%, 0-14%); (4) postural hypotension (3%, 0-24%); (5) Visual disorders (2%, 0-5%).

Comparison of our results with this classification is not straightforward. One of the reasons for this is that causes of falls can also be the dependent on other risk factors. An example is drug consumption, which is not considered in these studies, but which may cause vertigo, and which is itself a risk factor. Nonetheless, it is possible to estimate the GWs of these five causes using Tables 7 and 9. In fact, "balance disorders or weakness" are related to other risk factors such as "low muscular strength," and "loss of balance." Therefore, the GW of these would be 3.51 or 4.00, by summing the GWs of these two risk factors from Tables 7 and 9, respectively. Similarly, "dizziness/vertigo" is related to the risk factor "dizziness" and can be caused by "use of sedatives." Therefore, the GW of this would be 2.11 or 2.39, by summing the GWs of these two risk factors from Tables 7 and 9, respectively. Moreover, "confusion" is related to "low cognitive perception" and can be caused by "early stage dementia." Therefore, the GW of would be 2.10 or 2.08, by summing the GWs of these two risk factors from Tables 7 and 9 respectively. We considered "postural hypotension" and "visual problems" as independent RF, but in this case there is an inversion between these two RFs between our classifications and the one proposed in previous studies. In fact, postural hypotension is not in the first fifteen RFs of Table 7, and is considered less important than visual problems in Table 9. Although it is not possible to compare our results with previous classifications directly, this proposed prioritization, shows empirically that our results are broadly consistent with ones obtained from previous studies, at least regarding the most important causes of falls. Moreover, our research provides further insights regarding the hierarchy of risk factors and produces a measure of the divergence of opinion among experts.

3.9 Limitations of the study

As noted in section 3.2, the wording of the questions can influence the results of surveys. This is of particular importance when the questionnaire is submitted via the web with no direct feedback or contact with the respondents. For this reason, we tried to reduce any bias in the wording by editing the questionnaire as described in section 3.2. Nonetheless, possible bias in the wording, the sample size and not re-submitting the questionnaires to respondents with inconsistent responses, are the main limitations of this study. Further research could use a focus group with smaller number of experts to reach consensus using a more iterative approach.

4. Conclusions

In the study described in this paper, we investigated an adaptation of the AHP and how it could contribute to research assessing the priority of risk factors for falls in home-dwelling elderly people. Our conclusions are that the AHP can contribute to assessing the hierarchy of these risk factors. Moreover, it is useful to investigate a relatively broad spectrum of opinions across respondents. This could be due to the different backgrounds of the respondents, and we are investigating this hypothesis in an attempt to quantify any differences. The high number of risk factor individuated, the low difference between consecutive RIWs, and the relative high spread between the respondents' opinions do not allow us to identify a statistically significant punctual-scale of risk factors. Nonetheless, this study allows us clearly to individuate the factors considered the more relevant for falls compared with the less relevant ones. Further research could ask respondents to prioritize the most important risk factors. Nonetheless, the difference of opinion between respondents is in itself a primary outcome of this study. Further studies should try to investigate the reasons for this.

The implementation of the web system to submit blind questionnaires, allows a wide number of respondents to be reached. In addition, the time to complete the questionnaire was almost halved when the electronic version was used. Finally, no errors of compilation were registered, and users who completed both versions reported that the electronic version was more user-friendly and easier to use than the paper version.

The method suggested to correct the weights attributed to each respondent on the basis of its consistency (CR), allowed us to include a wider number of respondent without dramatic loss of significance in the final scale.

The next version of the web system will support a control of coherence, which in real time will suggest and underline respondents' inconsistencies. This control will ask respondents to review the comparison which presents the highest error, by comparing the ratio of the two corresponding elements of the eigenvectors to the corresponding value of the judgments matrix, as suggested by Saaty (1980, 1996).

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