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Article

Fall risk assessment in the safety management of ophthalmic care for patients with low vision

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Abstract: Patients with low vision face significant fall and caregiving risks due to impaired visual function, posing challenges to daily life and safety management. The aim of this study was to explore the application of fall risk assessment in the care safety of low vision patients and its scientific significance. The study designed a nursing intervention programme based on a risk assessment sheet and a smart warning device to quantify the patient's dynamic postural control through biomechanical techniques. The experimental grouping was based on the random number table method, and 75 low vision patients were divided into conventional and observation groups, and personalised interventions were implemented in the observation group through dynamic balance training, gait monitoring and environment optimisation. The results showed that the incidence of adverse events such as falls and nursing disputes in the observation group was significantly lower than that in the routine group. In terms of key kinematic parameters such as stride frequency, stride length and stride width, patients in the observation group showed significant advantages, indicating that the personalised nursing intervention effectively improved the dynamic stability and gait coordination of the patients. This study innovatively applies biomechanical technology to nursing practice, which provides a scientific basis for risk assessment and safety management of low vision patients, and at the same time promotes the development of precision and modernisation of the nursing model.

Keywords: fall risk assessment; biomechanics; low vision patients; eye care safety

1. Introduction

Low vision is one of the global health problems, the scope and depth of which is increasing with the ageing of society and the high prevalence of chronic diseases [1]. People with low vision have significant limitations in visual function that cannot be restored to normal vision through traditional spectacles, surgery or medication, severely affecting their daily lives and social adaptability [2]. According to the World Health Organisation, about 220 million people worldwide are currently suffering from moderate to severe visual impairment, with low vision patients accounting for a significant proportion. As shown in **Figure 1**, the number of people with vision loss worldwide has been increasing steadily between 1990 and 2020, especially in the categories of "near vision loss" and "moderate-to-severe vision loss". This increase reflects the accelerated ageing of the global population and the rising prevalence of chronic diseases. 2020 will see a significant increase in the number of people with "near vision loss" as the main driver of the increase in the number of people with vision loss, which is closely related to the proliferation of electronic devices and the high prevalence of presbyopia in the ageing population. Although "near vision loss" is a low life-threatening condition, its wide-ranging impact has led to a significant increase in the need for care interventions. At the same time, the steady increase in the number of people with "moderate-to-severe vision loss" reflects the far-reaching impact of chronic diseases on vision health, especially in low- and middle-income countries, where the lack of resources and coverage means that many patients do not receive timely interventions in the early stages of the disease, resulting in a continued deterioration of the condition to the moderate-to-severe stage.

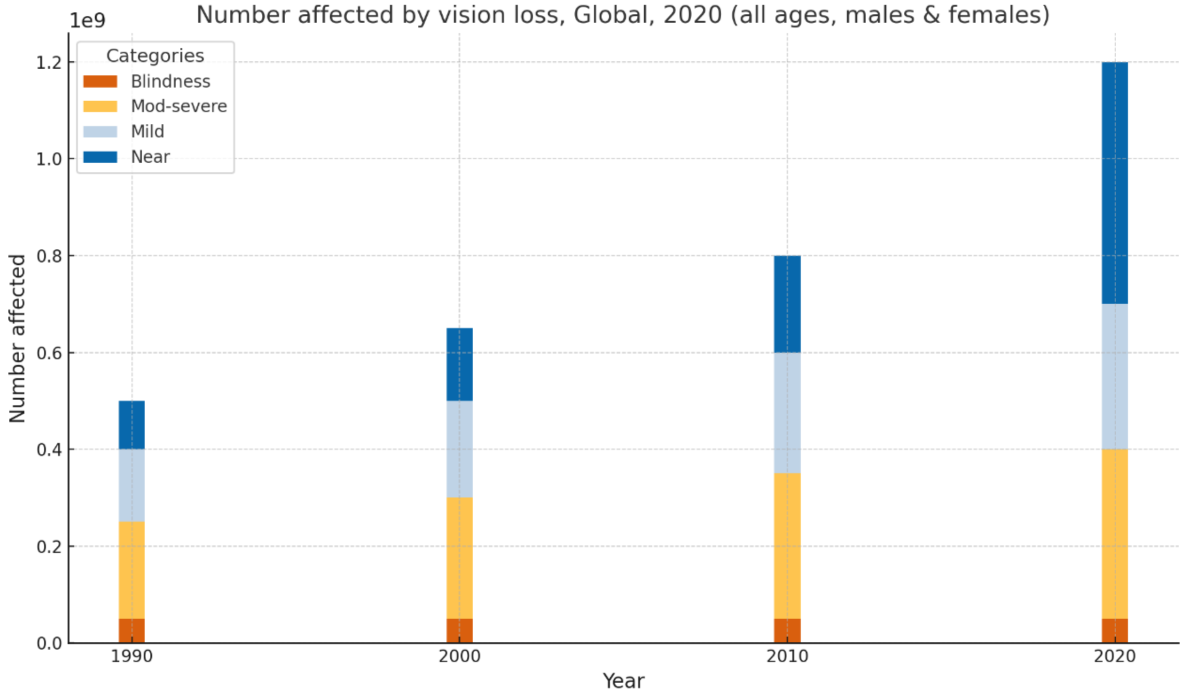

Figure 1. Global estimates of vision loss.

Data sources: VLEG/GBD 2020 model, accessed via the IAPB Vision Atlas.

In China, low vision is also of high public health concern. According to statistics, the total number of low vision patients in China is close to 10 million, with significant ageing and regionalisation. Due to the relative lack of medical resources in rural areas, patients are often unable to receive timely vision diagnosis and intervention, resulting in a continuous deterioration of their condition. In addition, the high prevalence of chronic diseases such as diabetes, glaucoma, and macular degeneration has made young and middle-aged people an emerging high-risk group for low vision problems [3]. This suggests that low vision is no longer just a health concern for the elderly, but a complex health challenge that cuts across multiple age groups and involves multiple etiological factors.

Low vision is not only about loss of visual function, but also about an individual's overall health, psychological state, and social adjustment. The loss of visual function directly affects the spatial perception and mobility of the patient, causing him/her to face many obstacles in daily life, such as the inability to perform self-care tasks and the loss of autonomy in travelling, etc. [4]. These problems further aggravate the social adjustment of the patient. These problems are further exacerbated by social isolation and psychological problems such as loneliness, depression and anxiety. Studies have shown that the prevalence of depression is four times higher in patients with low vision than in the general population, and such mental health problems, in turn, exacerbate the patient's dependence on care, creating a vicious circle.

From a nursing and healthcare management perspective, the special needs of low vision patients go far beyond traditional ophthalmic care [5]. The characteristics of low vision patients dictate that they require multidisciplinary and collaborative support in rehabilitation care, including integrated interventions in the fields of medicine, psychology, nursing, physiotherapy, and biomechanics. The goal of such interventions is not only to slow down disease progression, but also to help patients improve their quality of life and resume their functional roles in the family and society through scientific care measures. For example, through visual rehabilitation training and the application of assistive tools, patients can be helped to utilise their residual visual function to perform some daily tasks, thereby enhancing their independence [6]. In addition, environmental optimisation measures for low vision patients, such as light design and obstacle clearance in the home environment, can also effectively reduce the risk of accidental injury. These comprehensive care management strategies are significant in enhancing the overall health of patients.

At a time of rapid technological development, the introduction of modern technology offers more possibilities for low vision care management. For example, the development of biomechanical technology has made it possible to quantitatively analyse patients' dynamic balance ability and gait characteristics, providing data support for accurate care. In addition, the popularity of intelligent assistive devices, such as wearable sensors and vision aids, not only enables real-time monitoring of patients' physical status, but also predicts the risks patients may face through intelligent data analysis and provides early warning [7]. The development of these technologies has injected new vigour into the management of low vision care, and has also provided a scientific basis for further reducing the risk of falling and improving the quality of life of patients. However, the nursing management of low vision patients still faces many challenges. Due to the irreversible nature of low vision, there is often a lack of systematic follow-up care programmes for patients after receiving traditional ophthalmological treatments, which makes it difficult to improve their quality of life in a sustainable manner. The care needs of patients with low vision are highly heterogeneous depending on the etiology of the disease, the stage of disease progression, and the living environment, which complicates the development of care strategies.

Therefore, in this context fall risk is gradually receiving more attention as one of the core challenges in the care management of low vision patients [8]. Impaired visual function significantly weakens patients' spatial perception, balance control, and dynamic adaptive ability, which makes them more vulnerable to external factors and accidents in complex environments. Studies have shown that falls are not only one of the common complications in patients with low vision, but also an important cause of their increased disability and mortality rates. Therefore, scientifically assessing the risk of falling and taking timely preventive interventions from a nursing perspective has become a core aspect of safety management in the care of low vision patients. The visual system dominates human postural control, providing spatial perceptual information that can help the human body coordinate the position of the centre of gravity and plan gait patterns. However, patients with low vision rely more on perceptual mechanisms such as the vestibular system and proprioceptors for balance control due to severe deficits in the acquisition of visual information. This reliance is not entirely effective and instead increases the risk of compensatory imbalance. For example, when the environment is poorly lit, the ground is uneven or obstacles are present, patients have difficulty in making rapid adjustments through non-visual signals, which can easily lead to centre of gravity shifts and dynamic instability. In view of such complex risk characteristics, a single subjective nursing experience can no longer meet the care needs of patients with low vision, but must rely on scientific fall risk assessment tools and technical means to provide an objective basis for nursing interventions [9]. In ophthalmic nursing practice, fall risk assessment is a comprehensive process that combines individual characteristics, environmental factors, and dynamic behavioural patterns to quantify the likelihood of a fall. This process not only requires nursing staff to be proficient in assessment tools, such as the fall risk assessment form, but also requires the use of modern biomechanical techniques for dynamic monitoring and analysis. For example, biomechanics-based gait assessment can quantify key indicators such as the patient's stride length, stride frequency, contact time, and plantar pressure distribution, thus comprehensively reflecting his or her balance and movement stability. In addition, real-time monitoring of the patient's dynamic behavioural characteristics, such as the angle of body leaning forward and the trajectory of the centre of gravity swing, with the help of wearable sensors, also provides technical support for the timely detection of potential risks. The results of these quantitative analyses can not only be used for risk classification, but also provide an important reference for the development of nursing intervention strategies. The goal of nursing safety management is not only to reduce the incidence of falls, but also to ensure the safety and independence of patients' activities in daily life through early risk identification and real-time intervention.

Fall risk management in patients with low vision is an important issue that needs to be addressed in current ophthalmic care, and its research has significant theoretical significance and practical value. Falls are not only a serious threat to patients' physical health, but also have a profound impact on their psychological state and independence of life. The loss of visual function makes it difficult for low vision patients to accurately perceive their surroundings in daily life, leading to a decline in dynamic balance and reduced gait stability, which makes falls one of the major safety hazards for this group. At the same time, due to the obvious shortcomings of traditional nursing methods in risk identification and real-time intervention, how to use modern technology to carry out scientific assessment and precise management has become an important topic to improve the quality and safety of patient care. This study takes the combined application of fall risk assessment sheet and fall risk assessment early warning device as the core, and explores the new path of nursing care safety management for low vision patients from the perspective of scientific quantification. The lower half-limb movement characteristics were analysed by biomechanical technology to reveal the deep-seated influence of impaired visual function on the dynamic balance ability of patients. At the same time, the early warning device developed using sensing technology and artificial intelligence algorithms can monitor the patient's physical status in real time, and provide dynamic assessment and early warning hints for potential fall risks, so as to provide nursing staff with the basis for timely intervention. Based on this research, a personalised nursing intervention programme is designed, combining environmental optimisation, gait training and the use of assistive devices to comprehensively enhance the safety and independence of the patient's life. This scientific and precise nursing method makes up for the limitations of traditional empirical nursing and provides a new idea for the safety management of low vision patients.

This study has important theoretical value. Firstly, by introducing biomechanical technology and intelligent early warning devices, it combines the traditional nursing model with modern technological means, providing a theoretical basis and technical support for the scientific and precise nursing care of low vision patients. This data-driven risk management model not only promotes the development of nursing, but also deepens the application scenarios of biomechanical technology in medical care. Secondly, the study starts from the perspective of fall risk and systematically reveals the special needs of low vision patients in terms of dynamic balance and motor function, which provides a reference framework for subsequent related studies. On the practical level, by constructing a scientific fall risk assessment system and intelligent early warning devices, this study can significantly reduce the incidence of falls in low vision patients and fundamentally improve their safety and quality of life. Especially for elderly patients or high-risk groups with chronic diseases, the personalised nursing intervention plan can not only reduce the risk of physical injury, but also effectively alleviate the psychological pressure of patients, and enhance their autonomy and confidence in life. At the same time, the reduction of fall events means the saving of medical resources and the improvement of care efficiency, which reduces the economic and time burden for the patient's family and the social healthcare system. The application of early warning devices also promotes the intelligence and modernisation of care management, laying a technological foundation for the future digital transformation of the care sector.

2. Experimental materials and equipment

2.1. Subjects

The aim of this paper is to fully investigate the application of fall risk assessment in the safety management of ophthalmic care for low vision patients and its heterogeneity performance. To ensure the scientific validity of the study and the accuracy of the statistical analyses, the sample size was rigorously estimated using the GPower software, with a Type I error rate (α) of 0.05, an Effect Size of 0.25 (medium effect), and a Statistical Power of 0.95 [10]. The calculations showed that the minimum sample size requirement was 17 participants. In order to further improve the robustness of the experimental results and to reduce the impact of potential sample loss, this study planned to recruit 75 low vision volunteers (age >18 years) to participate in the experiment. Sample recruitment was carried out through offline publicity, community outreach and poster dissemination, with 40 males and 35 females eventually recruited to ensure a balanced gender distribution. The basic information of the subjects in the two groups is shown in **Table 1**. Comparison of the data between the groups showed no statistically significant difference at $P > 0.05$.

Table 1. Basic information of the subjects.

Group	Number	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Male	40	56.25 ± 1.57	166.40 ± 8.78	65.50 ± 11.31	23.60 ± 3.25
Female	35	56.63 ± 1.42	158.29 ± 3.53	60.49 ± 7.80	24.16 ± 3.20
P		0.796	0.141	0.426	0.792

Inclusion criteria included subjects being able to remain standing for at least 2 h during the experiment; not having participated in strenuous exercise within 24 h prior to the experiment and being able to co-operate well with the research team during the experiment; having no history of psychological, chronic or cardiovascular disease and having normal cognitive function and the ability to participate in the study. Exclusion criteria included a history of lower limb joint or neuromuscular disease (e.g., knee injury, tendon tear) or the presence of locomotor system dysfunction within six months; self-reported use of medications that may affect the central nervous system (e.g., antidepressants, sedatives, or anaesthetics); and the presence of other health problems that may interfere with the experimental results, such as an acute medical condition or a recent history of surgery. The homogeneity of the experimental samples and the reliability of the experimental data were ensured by strict inclusion and exclusion criteria [11].

The study strictly adhered to the Declaration of Helsinki and relevant medical ethics codes to ensure that the whole process of the study met the ethical requirements [12]. All subjects voluntarily participated in the experimental study and signed a written informed consent form after fully understanding the purpose of the trial, the study process, possible risks and benefits. The research team clearly informed the subjects of their right to withdraw unconditionally from the experiment at any stage, and that withdrawal would not cause any adverse effects on their life or health. In addition, the privacy of all subjects was strictly protected during the experiment, and the experimental data were recorded in an anonymised form for research purposes only [13].

To further enhance the scientific validity and reliability of the experimental results, the experimental conditions were strictly controlled in this study. The experimental environment was kept in moderate light and temperature to avoid the influence of external disturbances (e.g., noise, vibration, etc.) on the experimental results; for the use of equipment, calibrated biomechanical sensors and fall-risk warning equipment were used in the experiments to ensure the accuracy and reproducibility of the data; before the formal experiments, all the subjects underwent acclimatisation training to familiarise themselves with the operation of the equipment and experimental procedures, to ensure that the experimental process would be able to All subjects were trained to be familiar with the operation of the equipment and the experimental procedure before the formal experiment to ensure that they could co-operate with the research requirements during the experiment. During the data collection and analysis phase, the researchers monitored the operating status of the equipment and recorded the experimental data in real time, and the data were analysed in a blinded manner to ensure the objectivity and unbiasedness of the results.

In order to further protect the safety of the subjects, this study adopted a number of risk management measures. First-aid equipment and medical professionals were arranged to be on standby during the experiment to cope with potential accidents; the health status of the subjects was fully assessed before the start of the experiment, and a secondary review was conducted by medical personnel when necessary to ensure that all participants completed the experiment within the health range. The entire experiment is conducted under professional supervision to maximise the safety and comfort of the subjects.

2.2. Experimental materials and equipment

Training of medical personnel: The training program focuses on the operational skills of the equipment to ensure that nursing staff are proficient in the use of biomechanical assessment equipment and smart monitoring devices. Biomechanical devices and smart monitoring devices often require complex setup and commissioning, and caregivers need to spend some time in adequate training. Caregivers usually need at least two weeks of intensive training to master the basic operation of the devices, including device setup, commissioning, and initial data collection. The operating procedures of the devices are complex, and caregivers need to practice them repeatedly in real-world situations to ensure that they are proficient in each step. When using the Vicon Optical Motion Capture System, caregivers need to master the camera calibration, sensor positioning, and data synchronization steps of the device, and it usually takes five days of intensive training to initially master these operations. Training should also include data interpretation to help caregivers understand the complex data generated by biomechanical assessments and smart monitoring devices. Depending on the training program, caregivers typically need a week to two weeks to learn how to interpret gait data, balance tests, and other dynamic parameters fed back by the devices. For example, by analyzing key metrics such as gait cycle, stride length, and standing balance, caregivers are able to assess a patient's fall risk and adjust care accordingly. This part of the training focuses on how to translate the data output from the device into clinical care decisions, ensuring that the data matches the patient's specific condition. Caregivers typically need at least 10 days of training to be able to efficiently interpret this data in the clinic and adjust intervention strategies in a timely manner. To further minimize the learning curve for caregivers and improve operational efficiency, we recommend integrating a user-friendly interface into the device design. By streamlining the operational process, caregivers can familiarize themselves with the device more quickly, increasing efficiency and reducing human error.

Fall Risk Assessment Sheet: The design of the Fall Risk Assessment Sheet is based on the relevant system of hospital nursing management, combined with the professional characteristics of ophthalmology nursing, and at the same time, fully considering the hidden risks that may exist in patients with low vision. The assessment sheet is designed to help nursing staff identify high-risk patients quickly and accurately through systematic quantitative analysis of the fall risk of patients, and formulate targeted intervention measures, so as to reduce the incidence of falls and improve the level of nursing safety management. One of the main problems with a hierarchical system is that it oversimplifies complex, multidimensional objects or situations. In practice, especially for complex situations where multiple factors are intertwined, a grading system may not fully reflect the full picture of an individual or phenomenon. In fall risk assessment, although the grading system categorizes patients into low, medium, and high-risk levels according to the degree of risk, it tends to ignore important variables such as the individual patient's psychological state, environmental factors, and other important variables, which may result in failing to accurately capture the patient's actual risk. Therefore, this paper incorporates more dimensions and variables in order to improve the comprehensiveness of the assessment. The content of the assessment sheet covers the patient's basic information and multidimensional risk assessment elements, focusing on the following aspects: (1) age: those aged ≥65 years are identified as a high-risk group with a score of 1 due to the decline in muscle strength and weakened postural control caused by aging; (2) visual function: those with best-corrected visual acuity of the good eye in both eyes of the patient lower than 0.1 (i.e., the standard for low vision) are classified as high-risk group due to a significant decline in spatial perception is classified as a high-risk group, with a score of 1; (3) Balance or gait: whether the patient has any abnormalities, such as shortened stride, unstable gait, or shifted centre of gravity, etc., as determined by professional balance function tests or gait analysis, and if abnormal, the score will be 2; (4) Medication use: to assess whether the medication used by the patient has any effect on the central nervous system or balance. This includes sedative and sleeping medications (1 point), blood pressure lowering medications (1 point), glucose lowering medications (1 point), and pupil-dilating medications (1 point); (5) Chaperone status: patients without a chaperone are identified as high risk due to the inability to receive timely assistance, with a score of 2 points; (6) History of previous falls: patients who have had a fall in the past year are categorised as high risk due to the likelihood of unrecovered balance deficits or fear, with a The score is 2 points; (7) Lower limb function: patients were assessed for lower limb strength and flexibility, such as the presence of limited joint mobility, lower limb muscle weakness, etc., and those with abnormalities were given a score of 2 points. According to the assessment results, the patient's risk classification is as follows: no risk (0-1 points), the patient basically has no risk of falling and only needs routine care; mild risk (2–3 points), the patient has a slight risk of falling and the risk can be reduced through basic care and moderate monitoring; moderate risk (4–6 points), the patient has a high risk of falling and needs to take comprehensive preventive measures, such as dynamic monitoring, increasing escort, and strengthening the High risk (≥7 points), the patient's fall risk is very high, need to formulate a comprehensive, personalised nursing intervention plan, and combined with intelligent fall warning equipment for real-time monitoring [14].

Vicon Optical Motion Capture System: A three-dimensional camera motion capture system produced in the UK is used, which consists of 8 infrared cameras (model MX13) with 14mm diameter infrared reflective spheres, and the reflective spheres are located at the following positions: anterior iliac/posterior iliac spines of the bilateral knees, the medial and lateral condyles of the knees, the internal and external ankles of the bilateral ankles, the heel bones of the bilateral ankles, the bases of the bilateral second toes, the lateral third of the left thigh and the left calf, the right thigh and the right calf, and the left thigh and the right calf. left thigh and lateral third of the left calf, lateral third of the right thigh and right calf, anterior and inferior third of the left thigh and calf, and anterior and inferior third of the right thigh and calf. The lower limb model (Plug-In-Gait-CGM23) in the Vicon system was used to collect the kinematic data of the human lower limb during gait and obstacle crossing, and the sampling frequency was 100 Hz [15].

Kistler three-dimensional force measuring table: A Swiss-made Kistler three-dimensional force measuring table (90 cm × 60 cm × 10 cm) (Model: 9287B) was used to detect the force in the X, Y, and Z axes respectively, with a sampling frequency of 1000Hz, and synchronised with the Vicon Infrared High-Speed Motion Capture System through an analogue-to-digital converter [16].

Visual3D™ Biomechanical Analysis and Modelling Software: Visual3D™ biomechanical analysis and modelling software developed by C-Motion is used to process and analyse the kinematic and kinetic data collected by the Vicon Motion Capture System. It is used to process and analyse the kinematic and dynamic data collected by the Vicon motion capture system, and calculate the required biomechanical parameters through biomechanical methods and inverse dynamics analysis. The exported dynamic c3d file is imported into the professional biomechanical data processing software V3d for in-depth processing and index extraction. The static model of the lower limb was established according to the software model building method, and the ‘model-assign model to motion files’ was used to connect the static model with the dynamic data, and the ‘pipeline’ was used to low-pass filter the kinematic and dynamic signals. The kinematic and dynamic signals were low-pass filtered using ‘pipeline’, a fourth-order low-pass filter with a cut-off frequency of 6 Hz, and the lower limb hip, knee, and ankle joint moments were calculated by the inverse dynamics method using the ground reaction force and the three-dimensional kinematic data [17].

2.3. Experimental modalities

Application of the Fall Risk Assessment Sheet:

This study was conducted from January 2023 to January 2024, with a total of 75 subjects with low vision. To ensure the rigour and scientificity of the experiment, the patients were divided into the conventional group (37 cases) and the observation group (38 cases) based on the random number table method, and the basic conditions of the two groups were strictly matched to ensure a balanced baseline between the groups. Specific comparisons included: gender ratio, age distribution, visual function status, history of previous falls, history of chronic diseases and other variables, and the differences between the two groups were not statistically significant ($P > 0.05$), and were highly comparable. The age range of patients in the conventional group was 18–76 years old, with a mean age of (56.25 ± 1.57) years; the age range of patients in the observation group was 18-75 years old, with a mean age of (56.63 ±

1.42) years. In addition, the distribution of patients' visual function status was not statistically different in the two groups, ensuring a balanced experimental condition. Patients in the conventional group received traditional nursing interventions, which included setting up eye-catching fall prevention warning signs, providing fall prevention health education, and instructing patients in the correct use of assistive devices (e.g., wheelchairs or walkers) and other basic nursing measures. Nursing care focused on patients' environmental adaptation guidance and the provision of necessary supportive care, without using any additional scientific risk assessment or individualised interventions. Patients in the observation group implemented personalised nursing interventions centred on fall risk assessment in addition to routine care. This included a comprehensive quantitative risk grading assessment of the patients through a designed fall risk assessment sheet. Based on the assessment results, patients in the observation group were classified into four levels: no risk, mild, moderate and high risk, and targeted nursing measures were developed, such as health education and environmental optimisation for mild risk, dynamic balance training and increased companionship for moderate risk, and round-the-clock smart warning device monitoring and comprehensive nursing support for high risk. To ensure the scientific validity of the experiment, the study also set up the following control measures: (1) After the patients were grouped together, ensure that the nursing staff strictly differentiated between the intervention methods of the patients in the routine group and the observation group, to avoid crossover of interventions between the groups; (2) Risk assessment and grading of the observation group was independently completed by two experienced nursing staff and audited by a third party, to ensure that the results of the assessment were reliable; (3) The implementation of all the nursing measures were The whole process was recorded, including patient risk assessment data, nursing intervention details and nursing effect; (4) The completeness and authenticity of the experimental data were ensured through regular follow-up and data monitoring to avoid the impact of sample loss on the results [18].

The assessment of nursing effectiveness was based on the observation of the incidence of adverse events such as falls, injuries from falls and nursing disputes as the main indicators, and the number of occurrences of related events during the nursing process was counted by means of the whole process monitoring and event recording for the two groups of patients, and the total incidence rate was calculated. The effectiveness of nursing care was evaluated according to the number of events, and the lower the number of occurrences indicated a better nursing care effect, while the opposite was a poorer effect. During the study period, fall events were defined as accidental falls due to decreased balance or insufficient environmental adaptation; fall events included physical injuries caused by falls or other accidents; and nursing dispute events mainly referred to dissatisfaction or controversial issues raised by patients or their families about nursing services. The collection of these data strictly follows a standardised recording process, with dedicated staff responsible for monitoring and recording detailed information of all events, including the time of occurrence, location, cause, and follow-up measures to ensure the authenticity and completeness of the data. All records will be included in statistical analyses to verify the effects of different care models on patient care outcomes. Nursing care satisfaction was assessed by a self-developed nursing care satisfaction scale, which covers multiple dimensions of nursing services, including nursing service attitude, professionalism of nursing interventions, effectiveness of nursing measures, patients' sense of safety, quality of communication, and overall experience of nursing care. Patients and their family members rated the scale anonymously after the nursing care was completed, and the results were classified into four grades: 'very satisfied', 'satisfied', 'average' and 'dissatisfied'. The total satisfaction with nursing care was calculated according to the following formula: total satisfaction with nursing care = (number of very satisfied cases + number of satisfied cases) / total number of cases × 100%. This indicator is mainly used to reflect patients' subjective feelings about nursing services and the actual effects of nursing interventions. The nursing satisfaction assessment process emphasizes the objectivity and comprehensiveness of the data. At the conclusion of nursing care, a third-party member of the nursing team administers the satisfaction survey to both patients and their families, ensuring that nursing staff do not directly influence the responses. This approach helps guarantee that patients can freely and honestly express their true opinions. Furthermore, the design of the satisfaction scale has undergone multiple rounds of expert review and pilot testing to ensure that the content is both thorough and scientifically sound. Once the data is collected, it will be analyzed and summarized by independent statisticians to mitigate any potential bias or subjective influences on the results.

Application of early warning equipment for fall risk assessment:

The experimenter first carried out the operations of building, calibrating and setting the origin, and the subject entered the laboratory, and after entering the changing room to change the tight clothes and trousers worn during the test, morphological data measurements such as height, weight, left and right leg lengths (the distance from the ipsilateral anterior superior iliac spine to the inner ankle of the foot), left and right knee widths (the width of the medial and lateral knees of the ipsilateral knee), and left and right ankle widths (the distance between the inner and outer ankles of the ipsilateral foot) were taken, and used to systematically construct the skeleton model. Twenty-eight infrared reflective spheres were affixed with SM adhesive to the fixed positions required for the selection of the model, and the positions of the reflective spheres were: bilateral anterior/posterior iliac supraspinous spines, bilateral medial and lateral condyles of the knee joints, bilateral internal and external ankles, bilateral achilles, bilateral base of the second phalanx, left thigh and left calf at the lateral 1/3 position, right thigh and right calf at the lateral 1/3 position, left thigh and calf at the upper and lower 1/3 positions of the anterior aspect of the left thigh and calf, right thigh and calf at the upper and lower 1/3 positions of the anterior aspect of the right thigh and calf. The right thigh and lower calf were 1/3 of the way up and down the anterior side of the left thigh and lower leg. Prior to exercise data collection, a set of static data was collected from each subject to determine the anatomical position of the joints during post-processing. During static data acquisition, the weight on the force platform was zeroed first, and then the subjects were instructed to stand on the force platform for 5 s. The standing posture standards were feet shoulder-width apart, toes facing forward, both upper limbs at shoulder height, fingertips facing outward, palms facing downward, and both eyes looking straight ahead. After completing the above work, the action data collection could be carried out, the subjects entered the shooting area with bare feet, stood 70 cm away from the force platform to complete three complete obstacle crossing tasks, and at the end of the test, the infrared reflective sphere was removed, and the laboratory was tidied up, and the experiment was completed.

In this study, gait analysis of obstacle crossing was used to assess the dynamic postural control of the observation group and the conventional group. The experimental protocol was as follows: the force plate was set on the ground, and the height of 17 cm was the most consistent with the height of steps in real life, so the 17 cm hurdle frame was used as the obstacle in this study. Subjects were asked to stand in front of the start line 70 cm from the centre of the force plate, and when they heard the command ‘start’, they walked across the obstacle at their daily walking speed, in which the leg that crosses first is the swing leg and the leg that crosses second is the support leg, and after crossing the obstacle, they stood on the force plate to keep it as stable as possible, and maintained it for 20s before the test ended. If the subject hit the obstacle or stepped off the force platform during the crossing, the test was defined as unsuccessful, and three tests were conducted, each lasting approximately 30 s. Specialised personnel were available to ensure the safety of the subjects during the test. The delineation of moments during obstacle crossing is referred to Kuo et al. [19].

3. Effectiveness of the application of the fall risk assessment form

As shown in **Table 2**, in this study, the nursing outcomes of the observation group and the conventional group were comparatively analysed through the occurrence of falls, injuries from falls and nursing dispute events, and the data results showed that the observation group’s nursing outcomes were significantly better than those of the conventional group. In the 38 patients in the observation group, there were no adverse events, with an overall incidence rate of 0.00%, while in the 37 patients in the conventional group, a total of five adverse events were recorded, including three falls (8.11%), one fall (2.70%) and one nursing dispute (2.70%), with an overall adverse event rate of 13.51%. From the statistical analysis, the X^2 value was 5.501 and the P value was 0.018 ($P < 0.05$), suggesting that the difference in the incidence of adverse events between the two groups of patients was statistically significant. It can be inferred that the observation group significantly reduced the risk of falls, injuries and nursing disputes through the implementation of scientific risk assessment and personalised intervention, and the nursing effect was significantly better than that of the conventional group.

The observation group used a fall risk assessment sheet to conduct a comprehensive dynamic risk assessment of the patient during the nursing process, and developed a graded nursing programme based on the patient’s risk level (mild, moderate, high). This scientifically based care model captures patient safety risks in real time and effectively reduces the likelihood of falls or falls with targeted measures. For example, the dynamic balance training and environmental optimisation implemented for moderate-risk patients, as well as the intelligent early warning device monitoring provided for high-risk patients, helped to significantly reduce the incidence of falls. In addition, the observation group enhanced psychological support to alleviate patients' fear and anxiety caused by low vision, further reducing potential triggers for adverse events. In contrast, the conventional group only provided basic nursing services, including fall prevention warning signs, health education and necessary assistive device support. This conventional approach to nursing care lacked systematic risk assessment to effectively identify potential hidden risks in patients, especially in medium- and high-risk patients, and failed to provide targeted interventions, which led to the occurrence of falls and fall-related events. In addition, inadequate nursing communication may also contribute to the incidence of nursing disputes.

Table 2. Comparison of the effectiveness of patient safety management between the two groups [n (%)].

Group	Sample Size	Falls	Injuries	Nursing Disputes	Total Incidence Rate
Observation Group	38	0	0	0	0
Male (Chronic Disease)	10	0	0	0	0
Male (No Chronic Disease)	9	0	0	0	0
Female (Chronic Disease)	9	0	0	0	0
Female (No Chronic Disease)	10	0	0	0	0
Regular group	37	3(8.11)	1(2.70)	1(2.70)	5(13.51)
Male (Chronic Disease)	10	1(10)	1(10)	0	2(20)
Male (No Chronic Disease)	11	1(9.09)	0	0	1(9.09)
Female (Chronic Disease)	7	1(14.29)	0	0	1(14.29)
Female (No Chronic Disease)	9	0	0	1(11.11)	1(11.11)
X^2 value	5.501				
P value	0.018				

In terms of the total nursing satisfaction score, the total nursing satisfaction of the observation group was significantly higher than that of the conventional group, indicating that the personalised nursing model based on risk assessment not only has advantages in enhancing the nursing effect, but also significantly improves the patients' nursing experience and enhances the patients' acceptance of nursing services. Especially in the group of patients with low vision, this kind of scientific nursing care can effectively alleviate the psychological anxiety of the patients and improve their dependence on and satisfaction with nursing services. Specifically, the proportion of 'very satisfied' in the observation group was as high as 34.21%, much higher than that of 18.92% in the conventional group, reflecting that personalised nursing interventions are more advantageous in meeting patients' needs. On the other hand, the proportion of 'more satisfied' and 'dissatisfied' in the conventional group was higher, suggesting that traditional nursing interventions failed to fully meet the expectations of some patients. This difference further suggests that basic nursing care alone is not sufficient to meet the complex nursing needs of low vision patients, especially in terms of safety management and psychological support, and that conventional nursing interventions are not sufficient [20].

The results of the statistical analysis, with an X^2 value of 3.973 and a p-value of 0.046 ($p < 0.05$), further demonstrated that the difference in nursing satisfaction between the observation group and the conventional group was statistically significant. This result indicates that the nursing intervention model of the observation group has significant advantages in improving nursing satisfaction, which provides important data support for the optimisation of nursing management.

Further subgroup analyses showed that in the experimental group, no falls, injuries, or nursing disputes occurred in all patients regardless of gender and chronic disease status, suggesting that personalized nursing interventions were effective across patient subgroups to ensure patient safety. In the conventional group, patients with chronic conditions were at higher risk for falls, especially among men, demonstrating the impact of chronic conditions on falls and injuries. Male patients without chronic conditions were relatively safe but still at some risk of falls. The effect of chronic disease on fall risk in female patients was similar to that in male patients. There were no falls in the sample of females without chronic conditions, but there was one nursing dispute. Despite the absence of falls, nursing disputes in female patients may be associated with some deficiencies in standard care.

Table 3. Comparison of patient care satisfaction between the two groups [n (%)].

Group	Sample Size	Very Satisfied	Satisfied	Fairly	Unsatisfied	Satisfaction with Care
Observation Group	38	13(34.21)	20(52.63)	3(7.89)	2(5.26)	33(86.84)
Male (Chronic Disease)	10	3 (30)	6 (60)	1 (10)	0	9 (90)
Male (No Chronic Disease)	9	4 (44.44)	5 (55.56)	0	0	9 (100)
Female (Chronic Disease)	9	3 (33.33)	5 (55.56)	0	0	8 (88.89)
Female (No Chronic Disease)	10	3 (30)	4 (40)	2 (20)	2 (20)	7 (70)
Regular group	37	7(18.92)	18(48.65)	8(21.62)	4(10.81)	25(67.57)
Male (Chronic Disease)	10	2 (20)	5 (50)	2 (20)	1 (10)	7 (70)
Male (No Chronic Disease)	11	2 (18.18)	6 (54.55)	2 (18.18)	1 (9.09)	8 (72.73)
Female (Chronic Disease)	7	1 (14.29)	4 (57.14)	2 (28.57)	0	5 (71.43)
Female (No Chronic Disease)	9	2 (22.22)	3 (33.33)	2 (22.22)	2 (22.22)	5 (55.56)
X^2 value	3.973					
P value	0.046					

4. Effectiveness of the application of early warning equipment for fall risk assessment

In this study, the kinematic parameters during the obstacle crossing task were collected by the fall risk assessment early warning device, and the dynamic postural control of the patients in the observation group and the conventional group were quantified and analysed. The results, as shown in **Table 4**, showed that the patients in the observation group were superior to the conventional group in all key parameters, and the difference was statistically significant ($P < 0.05$). In terms of the percentage of single-leg support period, the low, medium and high-risk patients in the observation group were 0.47 ± 0.08, 0.47 ± 0.11 and 0.49 ± 0.06, respectively, which were lower than those of the conventional group (0.48 ± 0.12, 0.50 ± 0.08 and 0.51 ± 0.08), and in particular the medium and high-risk groups showed a significant advantage, which indicated that the observation group was more advantageous in terms of dynamic stability. Step frequency is a key indicator reflecting patients' movement coordination, and the step frequency of low-risk patients in the observation group was 1086.72 ± 38.47, which was higher than that of 952.52 ± 34.27 in the conventional group, with a highly significant difference ($P < 0.01$), and the step frequency of the medium- and high-risk groups was also significantly higher than that of the conventional group, suggesting that the patients of the observation group showed significant improvement in their gait coordination. In terms of step width and step length, the observation group had a smaller step width and a larger step length, both of which were better than those of patients of the corresponding risk class in the conventional group, which further indicated that the balance and gait efficiency of patients in the observation group were significantly improved. In addition, the index of the distance between the toe and the obstacle showed that the distance of the high-risk patients in the observation group was 172.65 ± 47.01, which was significantly smaller than that of the conventional group's 272.77 ± 39.24, reflecting that the patients in the observation group had a significant advantage in terms of the precision and safety of the crossing manoeuvre.

The experimental results fully verified the effectiveness of fall risk assessment and personalised nursing intervention in improving the dynamic postural control of low vision patients. The patients in the observation group significantly improved their gait stability and co-ordination through scientific risk assessment, dynamic balance training and intelligent device assistance, which was not only reflected in the near-normal performance of low-risk patients, but also in the significant improvement of medium- and high-risk patients. In particular, the superior performance of the observation group in key indicators such as step width, step length and toe-to-barrier distance indicates that its nursing intervention can significantly enhance patients' lateral and anterior-posterior balancing abilities, and reduce the risk of falling or collision during crossing barriers. In addition, the increase in step frequency and the decrease in the percentage of one-legged support periods further indicated that the patients in the observation group were able to complete the task in a more co-ordinated and efficient manner, demonstrating the significant role of nursing interventions in motor co-ordination.

Through the biomechanical parameters captured by the smart device, caregivers were able to quantitatively assess the dynamic postural control of the patients and formulate precise care strategies in combination with the fall risk assessment results, which helped to improve the safety management of low vision patients [21]. Especially for high-risk patients, the possibility of falls and fall injuries can be minimised by dynamically adjusting the care plan and real-time monitoring by intelligent warning devices. In addition, this study also provides new ideas for future nursing interventions for low vision patients—using objective data collected by biomechanical devices to scientifically and data-driven nursing care, which lays a practical foundation for the promotion of personalised care models. This study not only helps to improve patients' quality of life, but also provides important data support for further research on the relationship between nursing interventions and dynamic balance ability.

Table 4. Comparison of kinematic parameters between the two groups of subjects.

Norm	**Observation Group**			**Regular group**		
Pace(m/s)	Low risk	Medium risk	High risk	Low risk	Medium risk	High risk
Percentage of support leg single leg support periods	0.47 ± 0.08*	0.47 ± 0.11**	0.49 ± 0.06**	0.48 ± 0.12	0.50 ± 0.08	0.51 ± 0.08
Pacemaker	1086.72 ± 38.47**	1075.72 ± 50.13*	1066.49 ± 76.52*	952.52 ± 34.27	976.69 ± 52.47	994.20 ± 75.02
Step width	58.76 ± 16.96**	99.57 ± 41.97*	75.96 ± 23.16	96.99 ± 17.66	110.33 ± 40.16	153.91 ± 28.70
Stride length	760.80 ± 11.45	582.94 ± 95.67*	511.24 ± 85.96**	501.95 ± 12.64	482.72 ± 52.52	365.49 ± 63.27
Toe-to-Obstacle Distance	41.91 ± 21.72	153.92 ± 43.82**	172.65 ± 47.01**	65.47 ± 23 62	161.64 ± 47.36	272.77 ± 39.24

Note: * indicates a significant difference between the observation group and the conventional group ($p < 0.05$). ** indicates a highly significant difference between the male and female geriatric groups ($p < 0.01$).

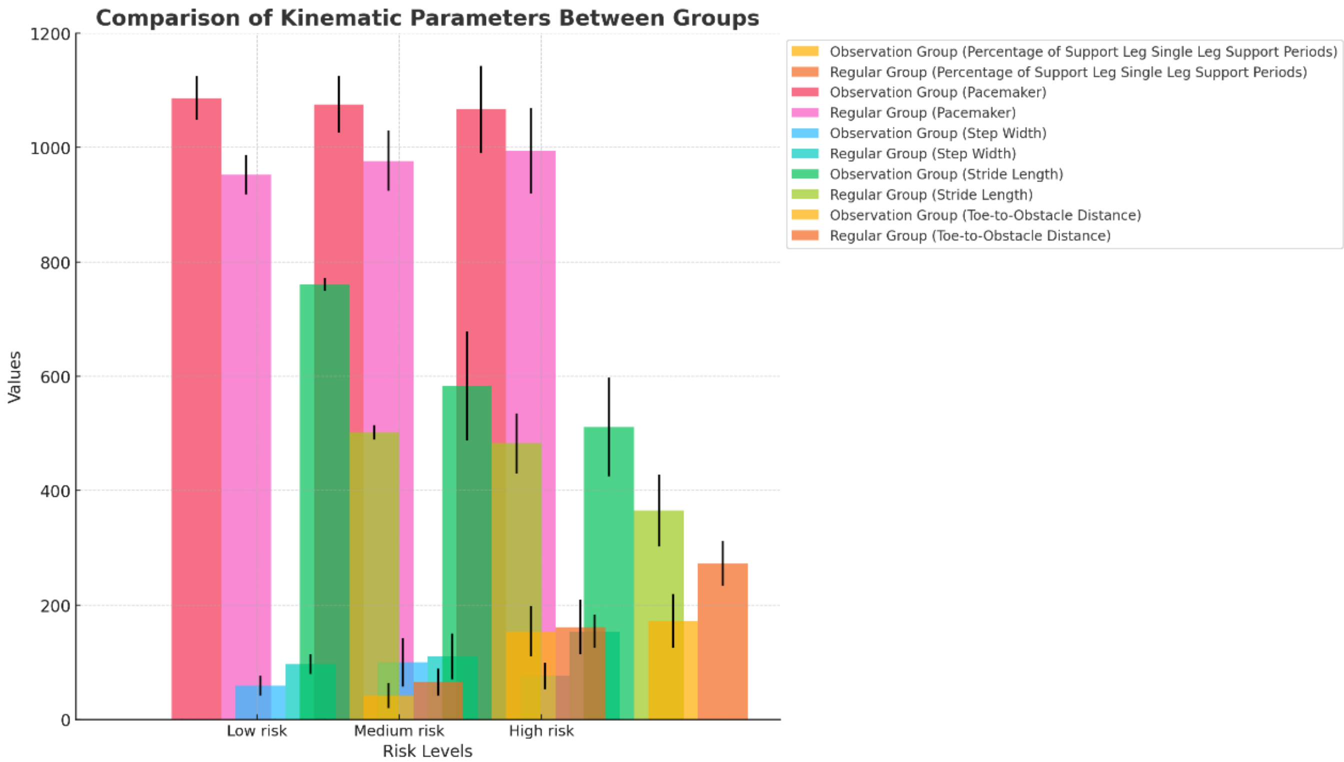

Figure 2. Comparison of biokinetic parameters between the two groups of subjects.

5. Conclusions and recommendations

5.1. Conclusion

This study systematically analysed the value of fall risk assessment in the safety management of ophthalmic care for patients with low vision by introducing the combined application of fall risk assessment sheets and intelligent warning devices, and quantified the patient's dynamic postural control with the help of biomechanical technology, which provided a theoretical and practical basis for the optimisation of scientific and precise nursing management. The results of the study showed that personalised nursing intervention based on fall risk assessment significantly reduced the incidence of adverse events in low vision patients. Patients in the observation group had no incidents of falls, injuries or nursing disputes during the study period, and the total incidence rate was 0.00%, which was significantly better than that of the conventional group, which was 13.51% ($P < 0.05$), reflecting the significant role of risk assessment and graded nursing interventions in preventing the risk of falls. This result fully demonstrates that the combination of scientific assessment and personalised nursing intervention can effectively identify and eliminate the hidden safety risks of low vision patients in their daily life, thus significantly improving the level of nursing safety. In terms of nursing satisfaction, the total nursing satisfaction of patients in the observation group reached 86.84%, which was significantly higher than that of 67.57% in the conventional group ($P < 0.05$). Patients in the observation group showed higher recognition in terms of nursing service attitude, nursing intervention effect and sense of safety. This result suggests that the personalised care model based on fall risk assessment can more accurately meet the individual needs of patients, and through risk identification, targeted interventions and psychological support, it significantly enhances patients' satisfaction and trust in nursing services, and further improves the overall quality of the nursing experience.

In addition, through quantitative analysis of dynamic gait parameters, patients in the observation group significantly outperformed the conventional group in key kinematic indicators such as step frequency, step length, and step width, showing an overall improvement in dynamic postural control. Specifically, the step frequency of low-, medium- and high-risk patients in the observation group was significantly higher than that of the conventional group, indicating that the movement coordination of patients in the observation group in the obstacle-crossing task was significantly enhanced; the step length was significantly longer than that of the conventional group, and the step width was significantly narrower, indicating that patients in the observation group had significantly improved their anterior-posterior and lateral dynamic balance abilities. Meanwhile, the distance between the toes of the patients in the observation group and the obstacle was significantly smaller than that of the conventional group, reflecting a significant improvement in the precision of the patients in the crossing task, thus reducing the risk of falling due to uncoordinated movements or obstacle collision. These results further suggest that risk assessment and nursing interventions based on biomechanical technology and smart devices can not only comprehensively enhance patients' dynamic balance, but also improve their gait efficiency and stability, providing strong support for their safety management in daily activities.

5.2. Recommendations

Based on the results of this study, in order to further optimise the nursing safety management of patients with low vision, it is recommended that a more systematic and scientific nursing management system should be constructed by promoting synergistically at multiple levels, such as nursing practice, technology application, resource allocation and policy guarantee. First, the construction of personalised nursing intervention system should be strengthened. Nursing staff should start from the individual differences of patients, accurately identify the risk characteristics of patients through the grading results of the fall risk assessment form, and dynamically adjust the nursing strategy. Especially for medium and high-risk patients, the focus should be on the improvement of their dynamic postural control ability, for example, through the introduction of balance training, gait adjustment and psychological support, to comprehensively reduce the risk of falling. For high-risk patients, real-time monitoring of dynamic behaviours should be combined with intelligent early warning devices, so as to achieve intelligent and forward-looking nursing interventions with the help of technological means. This 'person-specific' care model fits the concept of patient-centred care, which not only improves the quality of care, but also injects new connotations into the development of nursing science. Secondly, the deep integration of biomechanical technology in nursing should be vigorously promoted. The collection of patient gait data through high-precision biomechanical equipment can realise the precise quantification of the patient's dynamic postural control ability and provide data support for nursing intervention. It is recommended to develop biomechanical assessment tools specifically for low vision patients, integrate objective quantitative analysis into nursing practice, and gradually build a closed-loop management system from risk assessment to effect monitoring. Meanwhile, in the process of nursing intervention, a data-driven nursing model should be formed through intelligent equipment, continuously optimising the nursing process and promoting the deep synergy between technology and nursing. In addition, the improvement of nursing education and training system is an important guarantee to improve the level of nursing services. Nursing staff need to have the professional ability of risk assessment and equipment operation, so it is especially necessary to carry out regular professional training on fall risk assessment and application of intelligent equipment. At the same time, it is also necessary to strengthen the education of patients and their families, through popular science lectures, practical guidance and other ways to help them master the basic skills of fall prevention, forming a closed-loop management model of 'nursing-patient-family' multi-body collaboration. At the level of resource allocation, the popularisation and standardised application of intelligent equipment is a key link in improving the level of nursing management. The government and medical institutions should invest more in equipping primary medical institutions with intelligent early warning devices to narrow the nursing technology gap between different regions and institutions. At the same time, a nationally unified fall risk database should be established to provide a basis for optimising care programmes and resource allocation through standardised data processing. This will not only improve the overall efficiency of care management, but also provide strong support for the promotion of care models. Finally, policy protection and scientific research and innovation are the long-term paths to promote the sustainable development of nursing safety management. It is recommended that the government incorporate the care management of low vision patients into the social security and long-term care insurance system to reduce the financial burden of patients' families. At the same time, the government should formulate guidelines for the safe management of care for patients with low vision, so as to standardise nursing practice with uniform standards. In terms of scientific research, multidisciplinary cooperation among nursing, biomechanics and artificial intelligence should be promoted to develop smarter and more accurate nursing tools and verify their applicability in different scenarios, so as to provide theoretical and practical support for the modern development of the nursing field.

5.3. Research limitations and prospects

Although this study has yielded significant results through rigorous scientific design and implementation, several limitations remain, providing valuable directions for future research. Firstly, the relatively small sample size of 75 patients, while well-matched in baseline characteristics, may limit the generalizability of the findings, particularly for patients from diverse age groups and those with varying disease characteristics. This potential limitation could introduce bias. Future studies should aim to increase the sample size to include a broader range of low-vision patients with diverse demographics and health conditions, thus improving the external validity of the results. Secondly, the one-year observation period in this study is relatively short for assessing the long-term effects of nursing interventions, especially regarding their sustained impact on quality of life and fall prevention. Extending the follow-up period to multiple years would offer deeper insights into the lasting effects of personalized nursing interventions on functional rehabilitation, psychological well-being, and fall risk management.

In line with these findings and limitations, we recommend that future research incorporate more comprehensive assessment strategies. This should include objective measures such as automated monitoring data, independent evaluations, and nursing incident reports to complement self-reported satisfaction and minimize potential subjective bias. Additionally, integrating psychometric assessments (e.g., the Falls Efficacy Scale, FES) and utilizing machine learning algorithms could further refine personalized intervention strategies, providing more accurate and data-driven insights into patient needs. Given the economic and logistical barriers to widespread intervention implementation, especially in resource-limited settings and among elderly patients with lower levels of technical knowledge, we advocate for the development of cost-effective alternatives. For instance, smartphone-based applications or simplified wearable sensors could be promising solutions to increase the feasibility of fall risk assessments in various healthcare environments, improving accessibility across diverse populations. Moreover, it is crucial for future studies to include multicenter trials that encompass a wide variety of populations, age groups, and socioeconomic backgrounds. This approach will help validate the generalizability of the findings across different healthcare contexts and geographic regions. Additionally, these multicenter studies could examine the application of personalized interventions in varying healthcare resource settings to evaluate their broader utility.

Finally, the psychological consequences of fall risk—such as fear of falling, anxiety, and behavioral adaptations—are often overlooked but significantly influence patient outcomes. Future research should further investigate these psychological factors and integrate cognitive-behavioral therapy and resilience training as part of comprehensive fall prevention programs. This holistic approach could offer a more well-rounded intervention strategy to address both the physical and psychological challenges associated with fall prevention.

Conflict of interest: The author declares no conflict of interest.

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