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Marie Migeot

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Marie Migeot. Interventions for preventing falls after stroke: a systematic review. Human health and pathology. 2019. dumas-02884850

HAL Id: dumas-02884850

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UFR DE MÉDECINE DE GRENOBLE

Année : 2019

**PREVENTION DES CHUTES EN POST-AVC: REVUE SYSTEMATIQUE DE LA
LITTERATURE**

**INTERVENTIONS FOR PREVENTING FALLS AFTER STROKE:
A SYSTEMATIC REVIEW**

THÈSE
PRÉSENTÉE POUR L'OBTENTION DU TITRE DE DOCTEUR EN MÉDECINE
DIPLOME D'ÉTAT

Marie MIGEOT

[Données à caractère personnel]

THÈSE SOUTENUE PUBLIQUEMENT À LA FACULTÉ DE MÉDECINE DE
GRENOBLE

Le 21/10/2019

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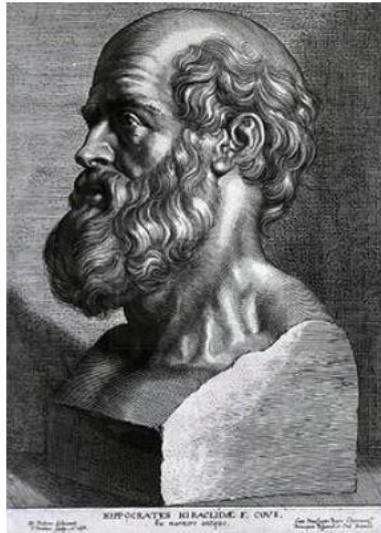
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SERMENT D'HIPPOCRATE

En présence des Maîtres de cette Faculté, de mes chers condisciples et devant l'effigie d'HIPPOCRATE,

Je promets et je jure d'être fidèle aux lois de l'honneur et de la probité dans l'exercice de la Médecine.

Je donnerai mes soins gratuitement à l'indigent et n'exigerai jamais un salaire au dessus de mon travail. Je ne participerai à aucun partage clandestin d'honoraires.

Admis dans l'intimité des maisons, mes yeux n'y verront pas ce qui s'y passe ; ma langue taira les secrets qui me seront confiés et mon état ne servira pas à corrompre les mœurs, ni à favoriser le crime.

Je ne permettrai pas que des considérations de religion, de nation, de race, de parti ou de classe sociale viennent s'interposer entre mon devoir et mon patient.

Je garderai le respect absolu de la vie humaine.

Même sous la menace, je n'admettrai pas de faire usage de mes connaissances médicales contre les lois de l'humanité.

Respectueux et reconnaissant envers mes Maîtres, je rendrai à leurs enfants l'instruction que j'ai reçue de leurs pères.

Que les hommes m'accordent leur estime si je suis fidèle à mes promesses.

Que je sois couvert d'opprobre et méprisé de mes confrères si j'y manque.

Remerciements

Au Pr Dominic PERENNOU, pour la rigueur, la méthodologie et le temps passé à la réalisation de ce travail. Merci également pour ces quatre années de formation et pour votre bienveillance. Pour l'opportunité que vous m'avez donnée de voyager et d'apprendre différemment.

Au Dr Laure MATHEVON, pour m'avoir beaucoup appris au cours de ce premier semestre au CHU! Le partage de tes connaissances, mais aussi l'écoute et la communication avec les patients, la rigueur et la joie de vivre. Les fous rires ! Merci pour tout !

Au Pr Olivier DETANTE, merci d'avoir accepté de faire partie de ce jury. Merci également pour vos visites mensuelles à l'IDR et les réponses à nos questions AVC !

Au Pr Pascal COUTURIER, merci d'avoir accepté de participer à ce jury.

Au Pr Marc HOMMEL, merci d'avoir accepté de participer à ce jury.

Un grand merci !

A mes parents, pour vos conseils, votre expérience et vos anecdotes d'anciens internes! Pour m'avoir montré « votre médecine », celle que j'aime. Pour votre soutien pendant toutes ces années de travail et pour m'avoir montré les limites à ne pas dépasser. Pour tous ces voyages et tous ces bons moments passés ensemble. Merci !

A mon frère, Jean-Baptiste (dit J-B !) pour tout ce qu'on a partagé depuis le début. Du tennistiquement parlant au médicalement parlant ! En passant par le ski, les Disneys, la danse, les jeux de société (et ce n'est pas fini) ! Merci enfin d'avoir été là dans les bons comme dans les mauvais moments. Merci à **Emilie** de veiller sur toi.

A mes grands-parents Vitteltois et Liverdunois. A ma grand-mère Lucie pour tout ce que tu nous as appris, pour nous avoir « Elevés » ; à mon grand-père François pour m'avoir transmis le goût de la photo et des voyages. A mes grands-parents de Vittel pour ces vacances inoubliables, le jardin, la cuisine, les randonnées... Merci !

A mes amies de la fac de Nancy ! **Coco, Chloé, Patate, Jeannou, Kristou, et à leurs coqs/poussins** ! Pour ces fous-rires, ces galas, ces soirées, les voyages ! Pour avoir supporté mes goûters d'amphi et mon tic clémentines pendant 5 ans ! Pour votre soutien. Et surtout, pour ces WE retrouvailles qui ne s'épuisent pas malgré la distance ! 😊

A mes Aixois préférés ! **Roger, Elo, Anne ptitchou, Charles ptitchou, Maël ptitchou, Anne-Passiflore et Isa-Benjam Préjent**. Pour avoir fait d'une coloc, la plus ouf des colocs ! Pour ces soirées, ces randos, le ski, les jeux ! Les concerts maisons, Sensodine, les conseils bio/écolos et tentes MSR... Pour tous ces bons moments (et ceux à venir) ... Merci !

Aux copains de l'internat : **Soso, Jo, Florent, Anne (et Rafiki !), Florian, Béné, Laura...** Pour avoir rendu ce 1er semestre encore plus beau ! Pour toutes ces randos, soirées et sorties ski/raquettes/raclette ! Merci !

A tous ceux qui m'ont entouré durant les stages.

L'équipe de rééducation neurologique du CHU et d'HDJ: à Anne C. pour m'avoir aiguillé durant ce premier semestre, pour tes conseils et ta bienveillance envers les patients, à Patrice D. pour tes conseils en toxine, spasticité et web-cam chamroussiennes ! A Marie J. pour tes

conseils en échographie. A Nath, Myriam, Elsa, Estelle, Laurène, Stéphanie et Laurie pour votre aide et surtout votre bonne humeur quotidienne !

L'équipe de rééducation neurologique d'Aix Les Bains : A Delphine L., Sylvie C. et Jean-François G. Pour votre expérience, vos conseils et merci de tout cœur Jean-François pour tout ce que tu m'as appris en appareillage, en uro-dynamique et en MPR tout simplement... Pour ton aide à la réalisation de mon mémoire de DIU et pour ton écoute, merci !

L'équipe de neurologie et de rééducation d'Annecy : Dr Ruel et tout son équipe, François B. et Stéphane V. Pour vos conseils dans le service ou en consultation toxine.

L'équipe de rhumatologie d'Aix Les Bains : Dr Gourmelen, Maxime C., Myriam R. et Claire V. Pour votre gentillesse et tous vos conseils pendant le DIU d'échographie.

L'équipe de rééducation orthopédique de Rocheplane : Christophe R., Sara V. Sabine R. et toutes vos équipes. Pour m'avoir fait découvrir la rééducation orthopédique. Pour votre bonne humeur et votre pédagogie. Merci !

A ma co-thésarde Liza, pour ton aide et tes conseils précieux à la réalisation de ce travail. Pour ton éternelle bonne humeur et ta positive attitude ! Pour ton soutien et ta relecture en dernière ligne droite 😊 Binôme de choc !

A tous mes co-internes : **Rémi** pour m'avoir hébergée x fois pendant cet internat, pour ton écoute (et mes pourrissages de bureau, grrrr), à **Greg et Helena** mes Parigos préférés et mon binôme de stage, à **Margo, Stan, Lénaïc, Camille, Flora, Adèle, Marie, Jean, Adélie, Ophélie, David, Solène, Marion et Antoine** : pour ces soirées jeux, restos, apéros et sorties ski qui ne s'arrêteront pas j'espère. J'ai encore besoin de conseils en ski de fond !

Et à toi mon **Aurélien**, mon soleil, mon cœur. Pour tous ces moments partagés ensemble ; pour ta bonne humeur, ton humour, ta joie de vivre ! Pour ton soutien dans les moments difficiles, et tous ces allers-retours pendant l'internat. Pour tout ce que tu m'as appris et m'apprends chaque jour. Pour m'attendre en vélo, pour supporter mon bazar (surtout pendant la thèse !), pour tes bons petits plats ! Pour cette complicité qui nous unit depuis presque 6 ans et qui va continuer de grandir ! Merci du fond du cœur !

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RÉSUMÉ

Introduction. La chute est une des complications les plus fréquentes après un AVC induisant peur de tomber et restriction de participation. La dernière revue de la littérature sur le sujet a été publiée en 2013.

Objectif. Mettre à jour les données de la littérature sur les moyens de prévention des chutes en post-AVC.

Méthodes. Une revue des bases de données Medline et Embase a été réalisée sur la période 1990-2019. Seuls les essais randomisés contrôlés en anglais ont été inclus. Ces articles ont été évalués indépendamment par 2 lecteurs grâce à une échelle basée sur l'échelle de Pedro et la SPS (standard dans le domaine de la prévention). Trois types d'intervention ont été définis : la rééducation, l'éducation thérapeutique et le contrôle de l'environnement.

Résultats. Douze études respectaient les critères d'inclusion. Parmi elles, huit ont eu une note $\geq 10/20$ et ont été analysées. Sept décrivaient une seule intervention et aucune d'entre elle n'a montré de résultats significatifs sur le nombre de chutes/chuteurs en post-AVC. La huitième étude était un programme de prévention des chutes comprenant des exercices individualisés à domicile, de l'éducation thérapeutique et du contrôle de l'environnement. L'essai était négatif malgré des résultats intéressants chez les sujets ayant totalement adhéré au programme.

Conclusion. Cette revue souligne l'inefficacité des interventions uniques dans la prévention des chutes en post-AVC. Les programmes de prévention incluant de l'éducation thérapeutique, un contrôle de l'environnement et des exercices individualisés semblent être prometteurs si l'adhérence des patients y est totale.

MOTS CLÉS : Accident vasculaire cérébral, prévention, intervention, chutes

FILIÈRE : Médecine Physique et Réadaptation

ABSTRACT

Introduction. Fall is one of the most frequent complications after stroke inducing fear of falling and participation restriction. The last literature review was published in 2013.

Objective. To update the literature about interventions preventing falls at any time after stroke.

Methods. We searched Medline and Embase databases from 1990 to 2019. Only randomized controlled trials in English were included. Papers were independently assessed by two reviewers with a scale (0-20) based on Pedro and SPS (Standard for Prevention science) scales. We defined 3 types of interventions: rehabilitation, fall education therapy and environment control.

Results. Twelve studies were found. Among them, we analyzed the eight which scored $\geq 10/20$ at the quality analysis. Seven studies described a single intervention. No one found significant results on the criteria “number of falls” or “fallers”. The tenth was a multifactorial falls prevention program comprising individualized home exercises, fall education therapy and environment control. The trial was negative despite interesting results found in individuals who fully adhered to the program.

Conclusion. Rehabilitation studies with a unique intervention are ineffective for preventing falls after stroke. Programs associating education therapy, environment control and home individualized exercises seem promising provided individuals fully adhere.

KEY WORDS: Stroke, intervention, prevention, accidental falls, falling.

DISCIPLINE: Physical and Rehabilitation Medicine

Introduction

Fall is one of the most frequent complication after stroke (1). During the first 6 months after discharge, the prevalence of falls among stroke survivors is between 36 to 73% and 40% of patients report at least one fall within the first year (2,3).

Falls may result in serious injury as fractures: incidence of hip fracture is up to 4 times higher in stroke patients compared with controls (4). Fallers had an increase fear of falling leading to a minor physical activity and restriction of social participation. Hence, falls may negatively impact participation in the rehabilitation program and increase length of stay. Fallers are more likely to be depressed and falls decrease quality of life. Moreover, caregivers of fallers were reported to be more stressed at 6 months poststroke compared with caregivers of non-fallers (5).

To date, many studies focused on epidemiology and risk factors of falls after stroke whereas a poor literature describes intervention program aimed at preventing falls after stroke. Two systematic reviews and meta-analysis in the subject were realized in 2010 and 2013 (6,7). The last one was updated in October 2019, after we finished our own work (8). Since 2013, almost 30 articles were published and a new synthesis of results was required.

Therefore, the purpose of this review was to assess the effects of any intervention aimed at preventing falls in people after stroke.

Methods

1. Study eligibility criteria

A systematic review of the literature was performed with two independent perusals in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (www.prisma-statement.org/). Only articles in English were retained. The inclusion criteria were:

- **Study design:** Randomized control trials.
- **Participants:** stroke survivors (aged 18 years old or more) at any stage after stroke. When study was not specific of stroke survivors, it was included if at least 50% of patients had a stroke and if separate data were available for stroke patients.

- **Interventions:** any prevention's program, treatment or intervention that may affect fall outcome were included. It could be any type of exercises (balance training, Tai-Chi, dual-task exercise...), at any time from the stroke onset (early exercises), or the use of devices (tDCS, whole body vibration...).
- **Outcomes:** studies were included if falls data (number or rate) or data about fallers were collected. Any form of measurement was included (eg, falls/1000 hospitalization days).

2. Exclusion criteria

Studies were excluded if they were not written in English. We excluded no-randomized controlled trials as well as studies where fall was considered as an adverse event. Furthermore, studies where falls and fallers' data missing were excluded (eg. Studies with only data about fear of falling).

3. Sources

The Medline and Embase databases from 1990 to 2019 were consulted. Search terms used were "Stroke OR brain infarct OR spastic hemiparetic OR spastic hemiplegic" and "rehabilitation OR treatment OR intervention OR prevention OR device" and "Fall OR Fall risk OR accidental fall".

4. Studies selected and data collection procedure

2705 articles were found in Medline and Embase databases, among them 306 were removed after duplicates. 2399 articles were reviewed: 1592 were excluded on title, 697 on abstract and 53 because they were written in other languages than English. We have to mention that two studies were secondly excluded because they had been retracted for author's misconduct after we began our review (9,10). Other studies were excluded because falls were not included as an outcome measure or were considered as an adverse event. See Figure 1.

Finally, a total of 12 randomized controlled trials were included in the review.

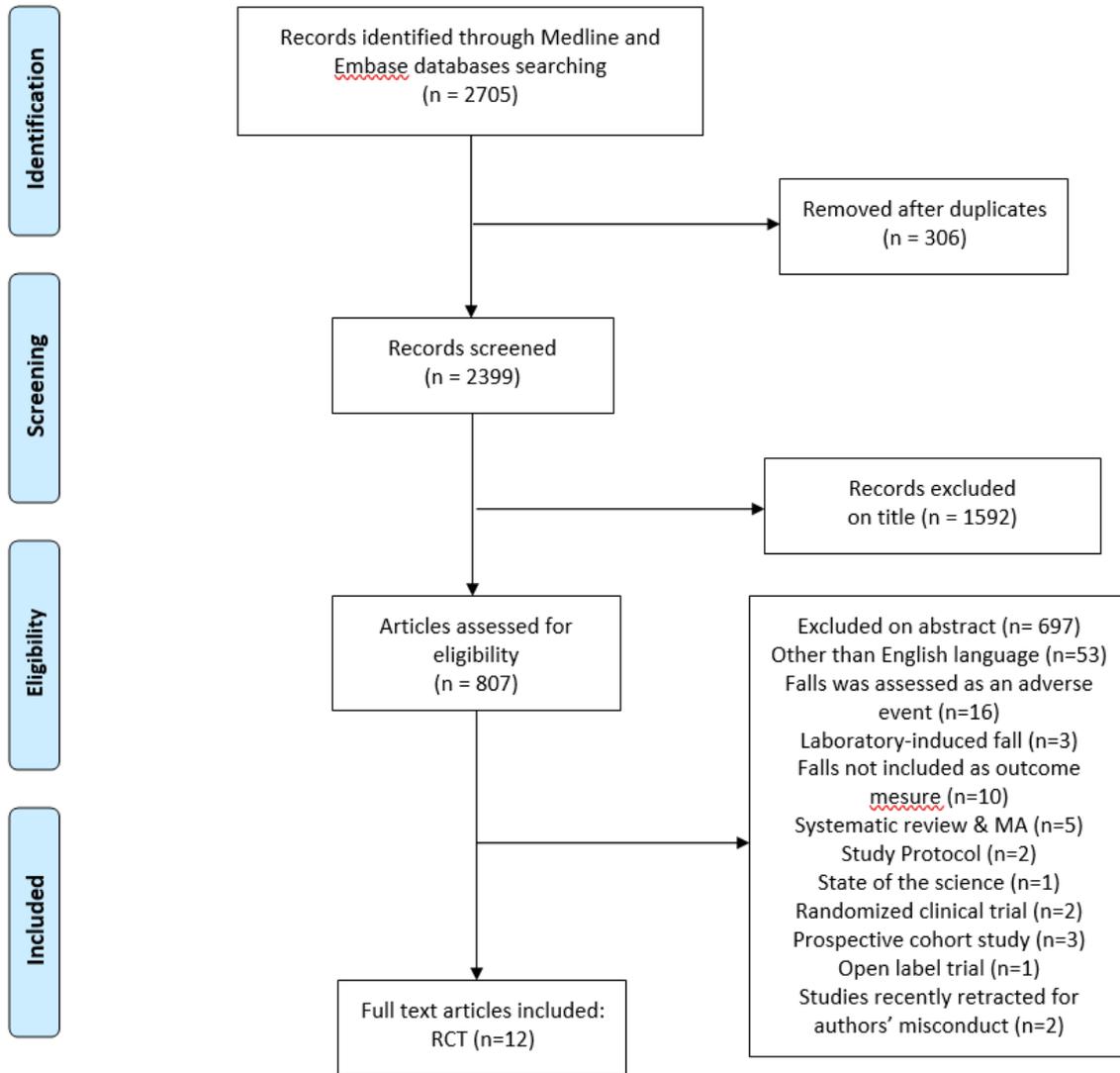


Figure 1. Flow chart of search results

5. Quality analysis

Once included, studies were evaluated for methodological quality with two methodological scales: the PEDro scale (Physiotherapy Evidence Database) and the SPS (Standard for Prevention science) (11). The PEDro scale assesses the quality of reports of randomized controlled trial. The SPS scale was created by the Society of Prevention Research to assess effectiveness of prevention study. For this systematic review, items from the SPS scale were essential because studies, dealing with a fall-risk reduction program, could not be assessed by the only PEDro scale. Therefore, items about compliance, adherence, number of sessions realized were added. Finally, we created a twenty-point scale (1 point per question) (see Table 1).

Two independent reviewers rated each 12 included studies (M.M and L.S). If scores differed, consensus was reached by discussion.

Table 1. The twenty-point scale based on PEDro scale and the SPS scale

	Introduction	YES	NO
Q1	A clear theory of causal mechanisms are stated		
Q2	The “fall” is clearly stated as the main outcome		
	Methods		
Q3	Eligibility criteria were specified		
Q4	Studies included patients at risk of falling or with mobility problem		
Q5	The intervention or treatment was clearly described allowing replication		
Q6	Individual factors of fall have been assessed before intervention		
Q7	There was blinding of all subjects		
Q8	There was blinding of all assessors who measured at least one key outcome		
Q9	The acceptance, compliance, adherence and/or involvement of the target audience in the intervention activities were measured and reported.		
Q10	Patients received fall educational therapy in addition to their intervention/treatment.		
Q11	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by “intention to treat”		
	Results		
Q12	There is a flow chart		
Q13	Subjects’ characteristics of both groups were similar		
Q14	The sample is sufficient: there are at least 100 people included		
Q15	Patients realized sufficient number of sessions (>twice a week, at least 2 months)		
Q16	Falls were assessed over a period of 6 months		
Q17	The subjects received an individually treatment according to their own risk of fall		
Q18	Side effects or iatrogenic effects are reported		
	Statistics		
Q19	The study has a $p < 0,003$ and conclude with a medium effect.		
	Conclusion		
Q20	The conclusion is consistent with the results		

6. Articles selection

For better quality, articles which scored $< 10/20$ were not included in the analysis because they could alter results.

Among the 12 articles included, 8 scored $\geq 10/20$ and were therefore analyzed (Table 2).

Table 2. Scores of the 12 articles

Articles	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	TOTAL /20
Pang et al. 2018	1	0	1	1	1	0	0	1	1	0	1	1	1	0	1	1	0	1	0	0	12
Mansfield et al. 2018	1	1	0	0	1	0	0	1	1	0	1	1	1	0	0	1	0	1	0	1	11
Andrade et al. 2017	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1	0	1	9
Morone et al. 2016	1	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	0	0	1	8
Piliae et al. 2014	1	1	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	1	7
Dean et al. 2012	1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	0	1	0	1	14
Batchelor et al. 2012	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	0	1	16
Lau et al. 2012	1	0	1	0	1	0	0	1	0	0	1	1	1	0	1	1	0	1	0	1	11
Duncan et al. 2011	1	0	1	1	1	0	0	1	1	0	1	0	1	1	0	1	0	1	0	1	12
Holmgren et al. 2010	1	0	1	1	1	0	0	1	0	1	1	1	0	0	0	1	1	0	0	1	11
Barreca et al. 2004	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	5
Green et al. 2002	1	0	1	1	0	0	0	1	1	0	1	1	0	1	0	1	0	0	0	1	10

Bolded text shows articles with average (10/20)

The median quality of the 8 selected articles was 12.1 (range 10 to 16).

Figure 2 shows the repartition's points for each question. Clear theory about mechanisms (Q1), assessor's blinding (Q8) and a conclusion consistent with the results (Q20) were checked in 90%-100% of articles. Items about individual risk factors assessed before intervention (Q6), subjects' blinding (Q7), fall education therapy (Q10), number of sessions realized (Q15), individual treatment according to patients' risk of fall (Q17) and studies with a $p < 0.003$ about falls data (Q19) were less represented, and thus, seemed to be more relevant to discriminate studies.

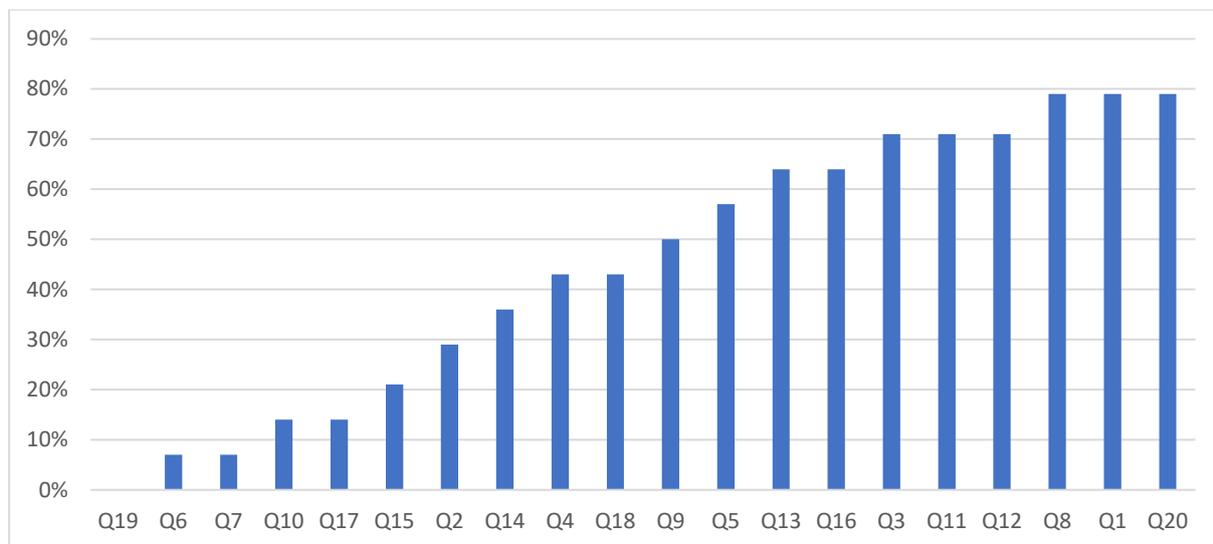


Figure 2. Allocation points for each item

7. Interventions' classification

We classified interventions into 3 main categories:

- **Rehabilitation** was dichotomized into 2 sub-groups: 1) Physical/Training activity as walking, sit-to-stand, dual-task training, perturbation-based balance training or 2) Passive neuromodulation as whole body vibration
- **Fall educational therapy** was defined by therapeutic education about risks of falls, and also advices preventing falls. It could be a group discussion or an individual teaching for patients or family caregivers.
- **Control of environment** could be advices about home's dangers (for example: no carpet, phone/wheelchair/rollator nearest patients) or prevention act from nursing staff.

Afterwards, studies were classified as "one type of intervention", or "several types of interventions" if there were more than one component.

8. Statistical analysis

Data were presented as raw mean (SD) and frequency (%). Because of small number of patients, statistical results were checked (D.P) for p values marginally inferior to 0.05. In one study, results found as significant by the authors with chi-2 tests were replaced by non-significant results with Fisher tests (12). No meta-analysis was performed given the few papers who positively concluded.

Results

Of the 8 studies, 3 did not provide fall definition (13–15). Two studies (12,16) used the Kellogg International Working Group definition (1987): “a fall is defined as inadvertently coming to rest on the ground or other lower level with or without loss of consciousness and other than as the consequence of sudden onset of paralysis, epileptic seizure, excess alcohol intake or overwhelming external force” (17). The 3 remaining studies (18–20) used a mixed definition: “falls were defined as incidents in which the individual, because of unexpected loss of balance, came to rest on the floor or an object below knee level”.

Table 3 shows the studies’ design, type of interventions, primary outcomes, and participants’ characteristics. Studies were carried out in 6 different countries: Canada 1, USA 1, China 2, Australia 2, United Kingdom 1 and Sweden 1.

1. Studies’ designs and types of interventions

All studies were randomized controlled trials, 5 were monocentric (9,11,13,16,18) and 3 multicentric (14,16,19) . The eight studies were performed in simple blinding (12–16,18–20).

All studies enrolled patient discharged at home (12–16,18–20). Interventions took place either in university or laboratory in 3 studies (12,13,18), at home in 3 studies (16,19,20), in community physiotherapy (15), in rehabilitation center or home (20).

Seven studies tested a single intervention: 6 tested physical exercises and training (12,14–16,18,20), one study assessed passive neuromodulation (13). Physical/training interventions were the following: dual-task exercise, perturbation-based balance training, Weight-bearing exercises, body-weight supported treadmill, high intensity functional exercise, agility exercise and general physiotherapy (without precision). Passive neuromodulation used whole body vibration (WBV). One study tested a program associating 3 types of interventions (19): educational therapy, environmental control, and rehabilitation.

Falls were monitored after the intervention in 4 studies (12,13,18,20), during the period of the intervention in 2 (16,19), and both for the 2 remaining studies (14,15).

The follow-up during which falls were monitored was always ≥ 6 months: 6 months in 3 studies (12,13,20), 9 months in one study (15), one year in 4 studies (15,16,18,19). Ways to monitor falls were satisfactory. Four studies (13,16,18,19) gave falls calendars to patients and a research assistant phoned them if they did not return documents by the due date. Two studies gave fall calendars without phone monitoring (14,20). One study phoned participants every month (12). The oldest study analyzed, published in 2002, assessed falls by interviews at home every 3 months during the study (15).

2. Outcome criteria

Measurement and ways of reporting falls varied between studies. Fall (number or rate) was the primary outcome in only 3 studies (16,18,19), and one of the secondary outcome in the 5 remaining studies.

Most studies assessed the intervention effectiveness by both fallers and falls data (12,13,16,18,19) and 3 studies used only fallers criteria (14,15,20). It could be comparisons before/after intervention in each group and comparison between the 2 groups after intervention (12) or only comparison between the 2 groups (13–16,18–20). Criteria were the total number of falls in each group before and after the intervention, the falls rate (as falls per person-year) in each group before and after the intervention, the rate of fallers in each group before and after the intervention, the number of recurrent fallers, or the number of falls with injuries.

3. Participants' characteristics

The eight studies gathered 1173 participants. They enrolled between 34 to 408 participants with a median sample size of 119.5 participants. Four studies had more than 100 participants (14–16,19), and one more than 200 (14). The mean age in the 8 studies was 64.5 years old (ranged from 57 to 78 years). Participants were mostly males (between 55% and 74%).

Six studies gave information about fallers before intervention: between 10% to 63% of patients were fallers before intervention.

Five studies concerned chronic stroke (> 6 months from onset disease) (12,13,15,16,18), and 3 concerned sub-acute stroke (from 15 days to 6 months). The mean delay from onset disease was 35.2 months. Stroke characteristics were poorly described, without detail on stroke location (even a simple information such as hemisphere, cerebellum, brain stem), information

on the first or recurrent stroke, or even the stroke side. Stroke etiology was mostly infarcts (between 50% to 79%) and the deficit was on the right side in 42 to 59% of cases.

Table 3. Characteristics of the 8 selected studies

		Author/year	Study design	Intervention	Falls = primary outcome (Y:Yes, N:No)	No of participants	Location	Age (years), mean \pm SD	Gender (% men)	Stroke phase	Delay from stroke (months) \pm SD	Ischemic stroke (%)	Right hemiparesis (%)	ITT analysis (Y: Yes, N:No)	Protocol	score/20
One type of intervention	Physical/Training	Pang et al. 2018 China	RCT	Dual-task balance/mobility exercise	N	84	Laboratory	61.2 \pm 6.4	71	Chronic	75.3 \pm 64.9	58	45	Y	60mn sessions/week for 8 weeks. IG (n=28) = Dual task group: forward walking, time-up and go-test, obstacle crossing test in single task and then with cognitive task (verbal fluency and mental tracking). Single-task training group (n=28) = only realized the 3 mobility tasks. CG (n=28) = upper-limb exercise group. After the end of the 8-week intervention period, the incidence of falls was recorded monthly for 6 months via telephone interviews.	12
		Mansfield et al. 2018 Canada	RCT	Perturbation-based balance training (PBT)	Y	88	Laboratory	66.5 \pm 7.5	67	Chronic	31.2 \pm 23.4	NC	47	Y	60mn training sessions/week for 6 weeks and two 1-hour "booster" sessions, 3 months and 9 months after the initial training period. IG (n=41) = PBT sessions: voluntary tasks intended to induce internal perturbations (such as kicking a soccer ball), voluntary tasks combined with external perturbations (push or pull from the physiotherapist). CG (n=42) = mobility and balance exercises. Participants were provided stamped addressed postcards containing a 2-week calendar to record falls for 12 months (after the initial 6-week training period). If a postcard was not return within 2 weeks, the research assistant called the participant to ascertain if they fell.	11
		Dean et al. 2012 Australia	RCT	Weight-bearing exercises for better balance (=WEBB)	Y	151	Community physiotherapy service	67 \pm 12	52	Chronic	70.8 \pm 73.2	NC	54	Y	One class weekly for 40 weeks over a 1-year period and a home exercise program completed at least 3 times/week. EG = WEBB program (=weight-bearing exercises for better balance). CG = exercises designed to improve upper-limb and cognitive functions. Falls were monitored monthly for 1 year with monthly fall calendars. Further contact was made by telephone if calendars were not returned.	14
		Duncan et al. 2011 USA	RCT	Body weight supported treadmill	N	408	Hospital / home	62 \pm 12.7	65	Sub-acute	2.12 \pm 0.3	71	55	Y	90 min sessions, 3 times/week, 12 to 16 weeks. Participants had to complete between 30 and 36 exercise sessions. Early locomotor training and Late locomotor training group received the intervention 2 months and 6 months after stroke, respectively. Intervention: stepping in a treadmill with partial body-weight support 20 to 30 min, followed by a progressive program of walking over ground for 15 min. CG= home-exercise program with task specific walking program. Participants recorded monthly any falls in a diary for 1 year.	12
		Holmgren et al. 2010 Sweden	RCT	High intensive program	N	34	Home	78.5 \pm 7.5	62	Sub-acute	4.41 \pm 1.1	73	NC	Y	5-week treatment period. IG (n=15) = high intensity functional exercise (HIFE): 45 min sessions, 6 times/week (lower-limb strength, balance, gait ability, two sets of 8-12 repetitions) + 1h/week educational discussion session (increased risk of complications after stroke, such as falls). CG (n=19): just 1h/week of educational session during the 5-week period about communication, fatigue, depressive symptoms, mood swings... (no special focus on the risks of falling). Fall calendars were used throughout the 6-month follow-up.	11
		Green et al. 2002 UK	RCT	Physiotherapy	N	170	Community physiotherapy service	72.5 \pm 8.5	56	Chronic	NC	NC	59	Y	A standard maximum contact period of 13 weeks with a minimum of 3 contacts/patient was agreed with the physiotherapists before the start of the trial. IG (n=85) = physiotherapy group (general physiotherapy). CG (n=85) = no treatment. Falls were recorded at 3, 6 and 9 months after baseline.	10

Table 3. (continued)

Three types of intervention = rehabilitation + educational therapy + environment control	Passive neuromodulation	Lau et al. 2012 China	RCT	Whole body vibration (WBV)	N	82	Laboratory	57.4 ± 11.2	71	Chronic	59.4 ± 42	50	58	Y	Each group received training 3 times a week for 8 weeks. WBV (Whole-body vibration) (n=41) performed exercises on platform (weight shifting, semi-squat, single leg standing...) with a frequency range of 20-30 hertz. In control group (n=41), subjects performed the same exercises while standing on the same platform but with no vibration. Subjects were given a logbook to record any occurrence of falls; the data were collected during a monthly telephone interview until 6 months after the end of training.	11
		Batchelor et al. 2012 Australia	RCT	Multifactorial falls prevention program	Y	156	Home	71.5 ± 10.6	63	Sub- acute	3.5 ± 1.8	79	42	Y	1-year treatment period. All participants received usual care from their health professionals (physiotherapy and occupational therapy). In addition, a physiotherapist provided participants in the IG a multifactorial tailored fall prevention program consisting of: 1) Individualized home exercise program (balance, mobility) 3-5 times weekly, 2) falls risk minimization strategies, 3) Education for participants and caregivers about identified falls risk factors and 4) Injury risk minimization strategies for those at high risk of fracture (hip protector, vitamin D supplementation). Participants completed information about falls each month returning calendar pages, for 12 months. A researcher phoned participants who did not return diaries within 2 weeks of the due date.	16

RCT: randomized controlled trial; IG: intervention group, CG: control group, N: no, Y: yes, NC: no communicated, SD: standard deviation, ITT: intention to treat

4. Effectiveness of interventions

Data are presented in Table 4.

No study reported significant results on primary criteria neither for fall or fallers criteria.

Two studies reported effectiveness on secondary criteria. One study (12) assessed dual task gait training during 2 months. Only stroke patients were included. Twenty-eight were allocated to the dual task group (comprising gait + various cognitive tasks involving memory, verbal fluency, mental tracking), and 28 in the control group (performing only upper-limb exercises). Each group realized 3 sessions/week for 2 months. Falls were recorded for a 6-month period post-training. The 28 individuals showed a decrease of their number of injurious falls during the 6 months follow-up: 0[0%] vs 6 [22%]; $p=0.023$ with the Fisher exact test we recalculated). Injuries included 8 bruising, one fracture and one bleeding.

One study tested a multifactorial fall prevention program (19). The study included 156 stroke participants, discharged home from rehabilitation. Among them, 71 were allocated to a tailored multifactorial fall prevention program which contained 4 types of intervention: 1) individualized home exercise program; 2) falls risk minimization strategies (based on general and stroke specific risk factors); 3) Education for participants and caregivers about identified falls risk factors and 4) Injury risk minimization strategies for those at high risk of fracture (vitamin D/calcium supplementation, hip protection...). Control group included 71 participants; they received usual care with their treating health professionals. Intervention lasted 12 months and falls were recorded during this time. Of the 64 remaining intervention participants (7 dropped-out), 25% fully adhered, 56.3% partially adhered and 18.7% did not adhere to the exercise program. There was a significant difference in the proportion of fallers to non-fallers across adherence category. The rate of falls was 66% lower in those who fully adhered than in those who partially adhered (IRR=0.34, 95%CI=0.15-0.78; $p=0.01$).

Table 4. Effects of intervention

Author/year	Number of falls					Fallers (%)					Conclusion
	Sample	Intervention group	Control group	Odds ratio	p	Sample	Intervention group	Control group	Odds ratio	p	
Pang et al. 2018		Not enough data to replicate statistics				22	12	37	NC	0.056 [†]	Dual-task program was not effective in reducing fallers after stroke compared to controls.
Mansfield et al. 2018	117	53	64	0.85	0.63	51	46	55	0.71	0.44	While this study found that perturbation-based balance training (PBT) did not reduce fall rates among the entire cohort, PBT participants improved on balance and mobility.
Dean et al. 2012	262	129	133	0.96	0.88	56	55	45	1.22	0.19	The WEBB (weight-bearing exercises for better balance) intervention delivered through stroke clubs enhanced aspects of mobility but had no effect on falls.
Duncan et al. 2012	NC	NC	NC	NC	NS	34	37	28	NC	0.07	Body-weight support on treadmill was not shown to be superior to progressive exercise at home managed by a physical therapist.
Holmgren et al. 2010	26	NC	NC	NC	NS	32	33	31	NC	0.9*	HIFE (High intensity functional exercises) including a home-based exercise program significantly improved the individuals own fear or falling but had no effect on falls.
Green et al. 2002	NC	NC	NC	NC	NC	31	35	27	NC	0.26	Community physiotherapy, one year after stroke, enhanced mobility for patients who had fallen in the 3 months before the study and patients who had very poor initial mobility but this effect was not sustained past 3 months. There were 30 and 23 fallers in the IG and CG respectively, but this did not reach significant (p=0.26)
Lau et al. 2012	6	3	3	NC	1	7	7	7	NC	1	The addition of whole body vibration to a leg exercise protocol was no more effective in reducing the incidence of falls in chronic stroke.
Batchelor et al. 2012	259	119	140	1.1	0.74	54	48	58	0.83	0.26	Of the 64 interventions participants for whom falls data were available, 25% fully adhered, 56.3% partially adhered and 18.7% did not adhere to the exercise program. The rate of falls was 66% lower in those who fully adhered than in those who partially adhered (IRR=0.34, p=0.01).

NC: no communicated, NS: no significant, * for these p-values we realized a chi-square test. [†] for these p-values we realized a Fisher test.

Discussion

Since 1990 to nowadays, few studies focused on the effects of interventions for preventing falls in people after stroke, and among them, few were randomized controlled trials (which is a main condition to compare interventions). Since the last systematic review published on the topic in 2013, about 30 new studies may be found in international databases. An update was necessary. We found 12 articles, from which we analyzed 8 which had a sufficient quality score ($\geq 10/20$). Two studies reported effectiveness on secondary criteria: the dual task program reducing number of injurious falls (12) and a multifactorial fall prevention program which reduced the rate of falls for participants who totally adhered to the intervention (19).

Most of studies reported non-significant results. We analyzed the possible influence of biases on this relatively negative result, using the Cochrane risk of bias tool (Higgins & Green, 2011).

1. Biases

1.1 Potential studies biases

Among the 8 selected studies, 3 studies did not include patients at risk of falls (13,16,18), although this should be a condition to propose an intervention for preventing falls.

The randomization process was optimal using computer-generated random allocation in 4 studies (16,18–20), was performed manually in 3 studies (12,13,15), and not reported or performed in 1 study (14). The allocation concealment was realized in 6 studies (12,13,15,16,18,19) and was not reported in 2 studies (14,20).

In most cases, fall was not the primary outcome of studies (12–15,20). This may have altered results because studies were not powered to detect differences in fall outcome.

In 6 of the 8 selected studies (13,14,16,18–20), falls in daily life was mainly obtained via self-report; this recall bias may have led to an underestimation of falls because of under-reporting (even if research assistant phoned in cases of missing diaries).

In all studies, participants were not blinded to the intervention (but it is well known that patients blinding is difficult with rehabilitation intervention). Assessors blinding was described in 100% of the 8 selected studies but group allocation blinding was violated in two studies (9,16).

Interventions' length and intensity may not have been sufficient to produce a significant effect. Rehabilitation of stroke patients is usually long due to sensory-motor deficit, spasticity, fatigue and also cognition impairment: comprehension and memorization can be altered making harder exercises realization. Therefore, interventions focused on fall prevention should have sufficient duration, intensity and frequency.

In addition to the intensity intervention prescribed, the percentage of sessions actually done by participants must also be considered (reflecting adherence to interventions). Five studies (12,15,16,18,19) gave information about patients' compliance: in 2 studies (12,18), more than 87% of sessions were realized by participants. Of the 3 remaining studies, less than 50% of sessions prescribed were attended. This is a main bias that could explain the lack of significant results.

An attrition bias with incomplete outcome data was also present. In the 8 selected studies, lost of follow-up ranged between 7% and 25% (whatever the cause: death, withdrawal, disease...). Moreover, all participants did not return falls calendars but percentage of respondents was correct, ranged between 70% and 100%.

Furthermore, interventions were nearly similar between intervention and control group in some studies (18) and sometimes participants had physiotherapy outside the study (14).

1.2 Potential biases in the review process

A selection bias is often present in literature review because all articles may not have been published yet. We searched in *clinicaltrials.gov* with key words: "Stroke" and "Fall prevention". Twenty-three articles were not yet completed or recruiting or with unknown status. Our quality analysis may induce another bias. Indeed, our scale may have a high level of requirement removing several studies. Moreover, we chose to build our own scale, and selected studies may have differed with a standard quality assessment tool

2. Results of the review

No study, assessing one type of intervention, reported significant effect on fall prevention after stroke. The multifactorial falls prevention program for people with stroke returning home after rehabilitation, supported by Batchelor et al.(19) reported positive results for secondary criteria: participants who fully adhered had a rate of falls 66% lower than

participants who partially adhered ($p=0.01$). This study, including physical training, education therapy and environment control, seemed to be the more effective for people after stroke than a single training intervention. Firstly, fall educational therapy may be essential in this population. Stroke survivors could have severe cognitive disorders with memory troubles and consequently difficulties to retain instructions. Education therapy on fall prevention should be realized several times to ensure a sufficient comprehension. Furthermore, fall risk factors after stroke have been largely described in literature; Patients and their caregivers should be advised of them. Secondly, control of environment is also primordial. Indeed, stroke survivors with impairments such as deficit of ankle-lifters, extracorporal neglect, may be less able to overcome obstacles at home. Therefore, caregivers and nurses should focus on safe environment.

A recent cluster-randomized controlled trial assessing an individualized fall prevention program in older people supported these hypotheses (21). Intervention group (IG) participants ($n=1623$) received for 50 weeks fall educational therapy (by DVD), set personal goals and staff helped them for environment control. Control group (CG) participants ($n=1983$) received usual care. There were significant differences between IG and CG for number of falls ($p=0.003$), fallers ($p=0.003$) and injurious falls ($p=0.006$). In that way, further studies should propose multifactorial program for preventing falls.

Today, few studies focus on dual-task training for preventing falls after stroke. However, dual-task reflects exactly gait in daily life: people walk while speaking most of the time.

One study, written by Tisserand et al. assessed the effect of a dual-task program (gait + cognitive tasks) on dynamic stability (22). Twenty-two participants (12 stroke survivors and 10 healthy subjects) realized single task (normal gait) and then four different dual tasks. Stroke participants presented a significant decrease in their cognitive performances during dual task compared to the cognitive assessment performed in sitting position ($p<0.05$). They supposed that post-stroke participants prioritized the control of dynamic balance beside cognitive performance to ensure safety while walking. Nevertheless, falls were not assessed in this review. Further studies are needed to confirm these results and evaluate the effectiveness on fall prevention.

3. Perspective for future studies

This systematic review highlights the need for new intervention programs to prevent falls in people after stroke. This requires understanding type of falls, a deep knowledge of fall risk factors after stroke, and a prevention program tailored to individual risk factors.

3.1 Understanding type of falls

Three types of fall were described previously by Morse et al. 1997:

- Accidental falls caused by environmental factors such as a wet floor, bed in an unexpectedly high position, absence of grab bars.
- Anticipated physiological falls resulting from:
 - o Intrinsic factors (sensitive or motor disorders, impaired vision, gait and balance...)
 - o Extrinsic factors (mobility aids, medication side effects, orthosis...)
- Unanticipated physiological falls, resulting from a sudden and unknown medical condition (heart attack, stroke...)

Accidental falls and anticipated falls may be avoided by respectively: environment control and an assessment of individualized risk factors at baseline.

3.2 Falls risk factors after stroke

The last meta-analysis in 2017 (2) focused on fall risk factors for stroke patient in community. The following risk factors had strong association with all fallers: impaired mobility, reduced balance, use of sedative / psychotropic medications, disability in self-care, depression cognitive impairment and history of fall.

However, in this meta-analysis, some risk factors were not investigated as urinary incontinence, pusher syndrome, lateropulsion, spasticity or spatial neglect.

In literature, we found 2 studies in Pub Med database where urinary incontinence was significantly associated with falls (23,24). No study assessed pusher syndrome, lateropulsion and spasticity as risk of falls. On the other hand, significant results were shown in several studies concerning spatial neglect (25,26).

Circumstances of falls were also described in the literature for inpatient rehabilitation: two-thirds of the stroke survivors fall indoors (27): patient's room or the lavatory were the sites of 83.3% of falls (28). Walking and transfers are the most frequently mentioned activities at the time of fall (27–31).

3.3 Redesigned fall prevention program for people after stroke

After understanding type of falls and individualized fall risk factors, studies should assess fall prevention program (than single intervention) with fall education therapy, physical training and environment control.

Conclusion

Falls are common after stroke. We performed a systematic review from 1990 to 2019 to update interventions aimed at preventing falls in stroke people. We analyzed primary and also secondary criteria of the studies. Single intervention alone is not relevant, perhaps excepted dual-task training which might decrease the number of injurious falls. Programs associating education therapy, environment control and home individualized exercises seem promising, provided individuals fully adhere.

THÈSE SOUTENUE PAR : Marie MIGEOT

TITRE :

INTERVENTIONS FOR PREVENTING FALLS AFTER STROKE. A SYSTEMATIC REVIEW.

CONCLUSION :

We performed a systematic review from 1990 to 2019. It seems that rehabilitation studies with a unique intervention are ineffective for preventing falls after stroke. The only single intervention with significant effects on falls was vitamin D supplementation at the dose of 1000 UI ergocalciferol per day. Programs associating education therapy, environment control and home individualized exercices seem promising provided individuals fully adhere.

VU ET PERMIS D'IMPRIMER

Grenoble, le : 30/09/19

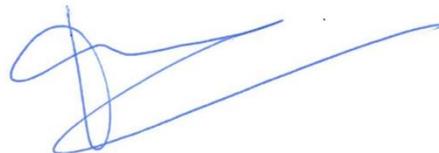
LE DOYEN



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