Part VI Summary
Summary

Pediculosis capitis and scabies are very common skin infestations. Head lice mainly affect children between 3 and 12 but adolescents and adults can also be infested. The prevalence of head lice differs from country to country. In industrialised countries prevalence rates around 10% are frequently reported but higher prevalences are not exceptional. Head lice infestations cause clinical lesions and physical discomfort but their medical importance mainly derives from their psychological, financial and social impact.

Scabies is not a life threatening condition but nevertheless it is a nuisance for the affected individual because of the rash and the intense and persistant pruritus that can be depressing and severely debilitating. Scabies however has a large impact on public health. It is estimated that each year 300 million new cases of scabies occur worldwide. Scabies is endemic in many resource poor communities. In developed countries on the other hand, institutions and social disadvantaged populations are particularly at risk for large outbreaks. The costs that are involved with the management of scabies in institutions are considerable.

A first step towards the development of an evidence-based management of pediculosis and scabies was to outline research questions that are crucial for rational therapy of head lice and scabies. With this thesis we attempted to find an answer to the research questions by systematically collecting all available evidence and by providing new evidence through original research.

A thorough literature search on both subjects revealed that there is much controversy about several elements crucial to the management of both diseases. Authors disagree on the use and value of diagnostic criteria and procedures and there is little research on the accuracy of diagnostic methods. There is a lack of uniform criteria to evaluate the existing and recently developed treatments and as a consequence there is no consensus on the value and place of the available therapeutic options. Furthermore, epidemiologic data are rare and many different statistical methods are used.
The diagnosis, epidemiology, treatment and management of pediculosis are discussed in the first part of this thesis and the same issues in the management of scabies are discussed in the second part.

The diagnosis of pediculosis is troubled by the lack of a gold standard for the detection of lice. A multitude of detection methods has been described but only two trials on diagnostic accuracy have been published. These studies showed that dry combing and wet combing are more accurate than visual inspection. In a recent study we have demonstrated that wet combing is more sensitive than dry combing and visual inspection. However, wet combing is an expensive and laborious method and is therefore less suited for routine screenings at schools. It is however the method of choice for a regular head check at home. Dry combing is more feasible for large screenings.

A large pediculosis screening on 6169 children has been performed in 2001 in Ghent, to measure the prevalence of pediculosis in this region but also to explore the role of different risk factors. Live lice were found in 8.9% of the children and another 4.6% had nits without lice. Clustering of children had a greater impact on the risk of getting head lice than the child’s individual characteristics. Nevertheless, SES, the number of children per family, hair length and hair colour were significant factors on the individual level. These results should be interpreted with care because there is not necessarily a causal relationship between the mentioned risk factors and the prevalence of lice. The risk factors probably lead to a higher prevalence because they hamper diagnosis or treatment.

It is currently difficult to give unequivocal advice on the treatment of pediculosis because there is no consensus on how clinical trials in this field should be conducted. The development of a systematic review is hindered because of the lack of a set of criteria to evaluate clinical trials. Furthermore, resistance trials are needed to explore the efficiency of the currently used pediculicides.

Until now, there has been little research on the treatment of eggshells or nits. Because no objective measurement procedure was described in the literature, we developed an affordable, feasible and reliable method to measure the force needed to remove nits from the human hair. An improved version of this measuring procedure was used to test the effect of several products on the force needed to
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remove nits from the human hair. Deionised water, a short application of commercial nit removal products and conditioner reduced the force needed to remove nits. However, a long application of ordinary conditioner or a commercial nit removal product greatly facilitated the removal of nits but there was no difference between the commercial product and the ordinary conditioner. Special ingredients such as formic acid had no additional effect.

Finally, in order to manage pediculosis, a policy should be developed that involves the whole community. Parents, teachers, school nurses, school administrators, pharmacists, physicians, local authorities as well as central government all play an important role.

The scientific research on scabies has to deal with similar difficulties as the research on pediculosis. The diagnosis of scabies is mainly based on an evaluation of the patient’s history and skin lesions. Diagnostic techniques and laboratory tests are of little help to the clinician.

The difficulty to establish the diagnosis of scabies might be one of the reasons why there are little reports on the epidemiology of scabies. Furthermore, these reports are often not representative for the population that Belgian physicians have to deal with. A prospective survey on the incidence of scabies in Ghent was organised in 2004 to explore the characteristics of scabies patients in our region. A higher incidence was found in persons over 75. This may reflect a growing problem of scabies within institutions for the elderly. We also found a higher incidence in immigrants. In the latter case nationality is probably an indicator of SES with immigrants having a lower SES. This survey also suggested that a considerable proportion of the scabies patients had to visit a physician more than once before the appropriate treatment was prescribed.

As far as the treatment for scabies is concerned, the evidence on which treatment advice should be based is rather flimsy. Clinical trials and systematic reviews are hampered by diagnostic and methodological problems. Nevertheless, experts more or less agree that permethrin cream is currently the treatment of choice. Other therapeutic agents such as benzyl benzoate lotion or crotamiton cream are less effective but can still play a role in the treatment of scabies, for example when the cost of treatment is an issue.
Recent trials have demonstrated the scabicide properties of ivermectin tablets. The role of this product in the management of scabies is not quite clear yet because only one study performed in an endemic area compared it to permethrin, the current standard treatment. Nevertheless, it can be a good alternative when a systemic treatment is preferred over a local treatment.

Finally, the management of scabies was also discussed. An evidence-based guideline for the management of scabies is currently being developed. From a general point of view, sufficient knowledge about a disease is a prerequisite for the adequate management of this disorder. A survey on the knowledge and management of scabies in GP’s and dermatologists in the region of Ghent showed that the knowledge level of both groups was of an acceptable level. The knowledge about scabies seemed to be increasing in physicians with more experience.

The relative good results on the knowledge test seem to be contradictory to the results of the epidemiologic study mentioned above. In the latter almost one quarter of the patients had to consult their physician more than once before the appropriate treatment was prescribed. It is possible that the knowledge test resulted in an overoptimistic estimation of the knowledge level. However, the discrepancy could also indicate that physicians have difficulties to translate their passive knowledge about scabies into practice.

The research described in this thesis has increased the knowledge on some aspects of the management of both scabies and pediculosis. However, there are some issues that remain unresolved and warrant further research. Furthermore, international consensus on diagnostic, epidemiologic and therapeutic principles are needed to further improve the management of these diseases.
Samenvatting


Scabieën is een andere, niet levensbedreigende huidziekte die toch zeer vervelend is voor de aangetaste personen omwille van de huideruptie maar vooral omwille van de intense en persistenderende jeuk die een belangrijke invloed kan hebben op het algemene welzijn van de patiënt. Scabieën heeft een belangrijke impact op de gezondheidszorg. Naar schatting komen er wereldwijd jaarlijks 300 miljoen nieuwe gevallen van scabieën voor. Scabieën is endemisch in verschillende ontwikkelingslanden. In geïndustrialiseerde landen echter lopen vooral personen in instellingen en sociaal zwakkere groepen risico op een epidemie.

Een eerste stap in de ontwikkeling van een op evidentie gebaseerd beleid voor zowel pediculosis als scabieën was het definiëren van enkele duidelijke onderzoeksfragen die centraal staan in het beleid van beide ziektes. In deze thesis werd geprobeerd om een antwoord te vinden op de onderzoeksfragen door middel van een grondige en systematische exploratie van de beschikbare literatuur en door nieuwe evidentie aan te brengen op basis van origineel onderzoek.

Uit een grondig literatuuronderzoek bleek dat er voor beide onderwerpen veel controverse is rond verschillende elementen die cruciaal zijn in het beleid. Experten gaan niet akkoord over de toepassing en waarde van diagnostische criteria en procedures en er is weinig onderzoek verricht naar de accuraatheid van diagnostische methodes. Er zijn geen uniforme criteria beschikbaar om de werkzaamheid van bestaande en nieuwe behandelingen te toetsen zodat er ook geen consensus is over de waarde en plaats van de beschikbare therapeutische
mogelijkheden. Daarenboven is er weinig epidemiologisch onderzoek beschikbaar en worden vaak verschillende statistische methodes toegepast.

De diagnose, epidemiologie, behandeling en aanpak van pediculosis worden besproken in het eerste deel van deze thesis, dezelfde elementen in het beleid van scabiës worden besproken in het tweede deel.

De diagnose van pediculosis wordt bemoeilijkt door de afwezigheid van een gouden standaard voor de detectie van luizen. Er werden veel verschillende methodes beschreven maar er werden slechts twee studies rond diagnostische accuraatheid gepubliceerd. Deze studies toonden aan dat droog kammen en nat kammen accurater zijn dan visuele inspectie. In een recente studie werd aangetoond dat nat kammen sensitiever is dan droog kammen en visuele inspectie. Nat kammen is echter duurder en arbeidsintensiever en is daarom minder geschikt voor de routine screenings op school. Het is echter de eerste keus voor een regelmatige controle thuis. Droog kammen is meer geschikt voor screenings op grote schaal.

In 2001 werden 6169 kinderen in de regio Gent gecontroleerd op hoofdluizen. De bedoeling van deze actie was om de prevalentie in de regio te meten maar ook om het belang van verschillende risico factoren te onderzoeken. Er werden luizen gevonden bij 8.9% van de kinderen en nog eens 4.6% had neten zonder dat er luizen aanwezig waren. De groep waartoe het kind behoort (bijvoorbeeld de klas of school) bleek een grotere impact te hebben op het risico om hoofdluizen te krijgen dan de individuele kenmerken van het kind. Op het individuele niveau bleken SES, aantal kinderen per gezin, haarlengte en haarkleur toch een rol te spelen. Deze resultaten moeten voorzichtig geïnterpreteerd worden omdat dit niet noodzakelijk betekent dat er een causaal verband is tussen de vermelde risicofactoren en de prevalentie van luizen. De risicofactoren vertonen wellicht samenhang met een hogere prevalentie omdat zij een vroege diagnose en adequate behandeling verhinderen.

Het is momenteel moeilijk om eenduidig advies te geven over de behandeling van pediculosis omdat er geen consensus is over de manier waarop klinische studies in dit onderzoeksdomein moeten uitgevoerd worden. Bovendien wordt de ontwikkeling van een systematische review bemoeilijkt door het gebrek aan criteria om de kwaliteit van klinische studies te beoordelen. Bovendien zijn ook studies naar resistentie nodig om de werkzaamheid te beoordelen van de pediculicides die momenteel op de markt zijn.
TOT NU TOE WERD ER WEINIG ONDERZOEK UITGEOORD NAAR DE BEHANDELING VAN NETEN. OMDAT ER GEEN OBJECTIEVE MEETMETHODE BESCHREVEN WAS IN DE LITERATUUR, WERD EEN BETAALBARE, BRUIKBARE, EN BETROUWBARE METHODE ONTWIKKELD OM DE KRACHT TE METEN DIE NODIG IS OM NETEN TE VERWIJDEREN VAN HET HAAR. EEN VERBETERDE VERSIE VAN DEZE MEETMETHODE WERD GEBRUIKT OM NA TE GAAN WELK EFFECT VERSCHILLENDE PRODUCTEN HEBBEN OP DE KRACHT DIE NODIG IS OM NETEN LOS TE MAKEN VAN HET HAAR. GEDÉIONISEERD WATER, EEN KORTE APPLICATIE VAN EEN AANTAL COMMERCIËLE PRODUCTEN OM NETEN TE VERWIJDEREN EN EEN KORTE APPLICATIE VAN GEWONE CONDITIONER VERMINDEREN DE KRACHT DIE NODIG IS OM NETEN LOS TE MAKEN. EEN LANGE APPLICATIE VAN ZOWEL HET COMMERCIËLE PRODUCT ALS DE GEWONE CONDITIONER HADDEN EEN NOG BETER EFFECT. ER WAS ECHTER GEEN VERSchIL TUSSEN HET COMMERCIËLE PRODUCT EN DE GEWONE CONDITIONER. EXTRA INGREDIËNTEN ZOALS MIERENZUUR HADDEN GEEN BIJKOMEND EFFECT.

WAT DE AANPAK VAN PEDICULOSIS BETREFT, MOET GESTREEFD WORDEN NAAR DE ONTWIKKELING VAN EEN BELEID WAARIN DE VOLLEDIGE GEMEENSCHAP BETROKKEN IS. OUDERS, LERAARS, SCHOOLVERPLEEGKUNDIGE, SCHOOLDIRECTIE, APOTHEKERS, ARTSEN, LOKALE EN OVERKEPELDE OVERHEDEN SPELEN ALLEN EEN BELANGRIJKE Rol.

HET WETENSCHAPPELIJK ONDERZOEK NAAR SCABIËS WORSTELT MET DEZELFDE MOEILIJKHEDEN ALS HET ONDERZOEK NAAR PEDICULOSIS. DE DIAGNOSTIEK IS VOORAL GEBASEERD OP EEN EVALUATIE VAN DE ANAMNese EN HudIetSELS. DIAGNOSTISCHE TECHNIEKEN GEVEN VAAK WEINIG BIJKOMENDE INFORMATIE.

SCABIËS IS SOMS MOEILIJK TE DIAGNOSTICEREN. WAARSCHijnLIJK IS DIT ÉÉN VAN DE REDENEN WAAROM ER VRIJ WEINIG EPIDEMIологИЧSCH ONDERZOEK IS NAAR SCABIËS. BOvendien ZIJN DE GEПУBлицЕerde EPIDEMIологИЧSCHе ONDERZOEKEN NIET ALTijd REPRESENTATIEF VOOR DE GEMIDDELDE POPULATIE WAARMEE BELGISCHe ARTSEN IN CONTACT KOMEN.

IN 2004 WERD EEN PROspectieve STUDIE IN GENT UITGEOORD OM DE INCIDENTIE VAN SCABIËS TE METEN MAAR OOK OM DE KENMERKEN VAN SCABIËS PATiëNTEN Binnen DEZE REGIO TE VERKENNEN. ER WERD EEN HOGERE INCIDENTIE VASTGESTELD BIJ PERSONEN OUDER DAN 75 JAR. DIT WIJST MOGLIJK OP EEN GROEIEND PROBLEEM VAN SCABIËS Binnen Rust- en verzorgingstehuizen. Er werd ook een hogere incidentie vastgesteld bij immigranten waarbij de nationaliteit van de patiënt waarschijnlijk een indicator is van SES (met een lagere SES BIJ immigranten). De resultaten van deze studie suggereren ook dat een vierde van de patiënten meerdere keren een arts consulteerde voor de diagnose van scabiës werd gesteld of een aangepaste behandeling werd voorgeschreven.
De evidentie waarop het behandelingsadvies voor scabiës gesteund wordt is eerder mager. De uitvoering van klinische studies en systematische reviews wordt gehinderd door diagnostische en methodologische problemen. Toch wordt permethrine crème als voorkeursbehandeling beschouwd door de experten binnen dit domein. Andere behandelingsopties zoals benzyl benzoaat lotion of crotamiton zijn minder werkzaam maar kunnen toch een rol spelen in de behandeling van scabiës, bijvoorbeeld wanneer de kostprijs van de behandeling een belangrijk punt is voor de patiënt.

Recente studies hebben aangetoond dat ivermectine tabletten ook werkzaam zijn tegen scabiës. Het is nog niet helemaal duidelijk welke rol dit product kan spelen in de aanpak van scabiës, omdat er nog geen vergelijkende klinische studies werden uitgevoerd in een representatieve, West-Europese populatie. Toch is ivermectine een goed alternatief wanneer een systemische behandeling te verkiezen is boven een lokale behandeling.

Tot slot werd de aanpak van scabiës besproken. Momenteel wordt een op evidentie gebaseerde richtlijn voor de aanpak van scabiës ontwikkeld. Vanuit een algemeen standpunt kan gesteld worden dat voldoende kennis over een bepaalde aandoening noodzakelijk is om een correct beleid te kunnen voeren. In een studie rond de kennis en aanpak van scabiës bij huisartsen en dermatologen in de regio Gent werd aangetoond dat de kennis van beide groepen voldoende is. De kennis over het onderwerp nam toe bij artsen met meer ervaring. De resultaten van de bovenvermelde epidemiologische studie lijken echter de resultaten van de kennisstorting tegen te spreken omdat een aanzienlijk aandeel van de patiënten verschillende keren een arts consulteerde voor een werkzame behandeling werd voorgeschreven. Het is mogelijk dat de kennisstorting een te optimistisch beeld gaf van de kennis. Het verschil kan echter ook betekenen dat artsen misschien voldoende passieve kennis hebben over het onderwerp maar niet in staat zijn die kennis over te brengen in de praktijk.

Het onderzoek dat beschreven werd in deze thesis heeft bijgedragen tot de kennis van sommige aspecten in de aanpak van zowel scabiës als pediculosis. Er blijven echter nog steeds een aantal onopgeloste problemen die in de toekomst verder onderzocht dienen te worden. Bovendien zouden internationale afspraken rond diagnostische, epidemiologische en therapeutische beginselen de aanpak van beide ziektes alleen maar ten goede komen.
Résumé

La pédiculose et la gale sont deux infestations de la peau fréquemment observées. Quoique la pédiculose atteigne surtout les enfants entre 3 et 12 ans, on rencontre pas mal de cas chez les adolescents et les adultes. La prévalence des poux diffère d’un pays à l’autre. On estime une prévalence d’environ 10% dans des pays industrialisés mais des chiffres plus hauts ne sont pas rares. La pédiculose cause des lésions cutanées et des gênes physiques mais surtout des problèmes psychologiques, financiers et sociaux. Quoique la gale ne soit pas une condition mortellement grave, elle peut être la source de grands ennuis à cause de l’éruption cutanée et surtout à cause du prurit persistant, déprimant et gênant. La gale a aussi un impact important sur la santé publique. Le chiffre de 300 millions de nouveaux cas de gale par an dans le monde est proposé. La gale est endémique dans beaucoup de pays du tiers-monde. Dans les pays développés on rencontre des problèmes chez les personnes séjournant dans des institutions ou chez les individus défavorisés au plan social. Les coûts pour combattre la gale dans une institution sont souvent importants.

L’objectif de la recherche qu’on a réalisée était de développer une approche, fondée sur des données évidentes, de la pédiculose et de la gale à l’aide d’une exploration et une critique de la littérature disponible. En plus, on a tâché à l’aide d’une recherche originale de résoudre des questions pour lesquelles on n’avait pas encore trouvé de réponse.

Une analyse minutieuse de la littérature sur les deux sujets, a découvert qu’il existe beaucoup de controverses sur des éléments cruciaux pour l’approche des deux maladies. Les auteurs ne sont pas d’accord sur l’usage et la valeur des critères et des procédures de diagnostic et il n’y a que peu de recherche sur la précision des méthodes diagnostiques. On manque des critères uniformes pour évaluer les traitements déjà disponibles et les produits nouveaux. Par conséquent, il n’y pas de consensus sur la valeur et la position des alternatives thérapeutiques. En plus, des
données épidémiologiques sont rares et beaucoup de méthodes de statistique différentes sont utilisées.

Le diagnostic, l’épidémiologie, le traitement et l’approche de la pédiculose et la gale sont discutés dans la première partie de cette thèse de doctorat, les mêmes thèmes dans l’approche de la gale sont discutés dans la seconde partie.

Le diagnostic de la pédiculose est compliqué par l’absence d’une méthode de référence pour la détection des poux. De nombreuses méthodes ont été décrites mais il n’y a que deux études sur la précision diagnostique. Ces études ont démontré que l’inspection à l’aide d’un peigne fin et l’inspection utilisant un peigne, de l’eau et un baume sont plus précises que l’inspection purement visuelle. Une étude récente a démontré que l’inspection à l’aide d’un baume est plus sensible que l’inspection à l’aide d’un peigne fin et l’inspection purement visuelle. L’inspection à l’aide d’un baume est plus coûteuse, prend beaucoup de temps et convient moins pour des contrôles de routine à l’école. Cette méthode est toutefois la méthode préférée pour faire un contrôle régulier à domicile. L’inspection à l’aide d’un peigne fin convient peut-être mieux pour des contrôles d’une grande population.

En 2001, 6169 d’enfants à Gand ont été inspectés sur la présence des poux. Le but était d’établir la prévalence de la pédiculose dans cette région mais aussi d’explorer le rôle des différents facteurs de risque. Des poux vivants ont été retrouvés chez 8.9% des enfants et 4.6% présentaient des lentes mais pas des poux. Mettre des enfants ensemble dans un même groupe (classe, école) avait un plus grand impact sur le risque d’être atteint par la pédiculose que les caractéristiques individuelles de l’enfant. Toutefois, la position socio-économique, le nombre d’enfants par famille, la longueur et la couleur des cheveux étaient des facteurs significatifs sur le niveau individuel. Les résultats doivent être interprétés prudemment car il n’y a pas nécessairement une relation causale entre les facteurs de risque et la prévalence des poux. Les facteurs de risque mènent probablement à des chiffres de prévalence plus élevés parce qu’ils empêchent un diagnostic précoce et un traitement adéquat.

Pour le moment il est très difficile de donner un avis universellement accepté sur le traitement de la pédiculose parce qu’il n’y pas de consensus sur la façon de conduire des études cliniques. Le développement des revues systématiques est empêché par l’absence des critères pour évaluer des études cliniques. En plus, on a besoin d’études de résistance pour juger de l’efficacité des pédiculicides.
Jusque maintenant, il y avait peu de recherche sur la façon d’enlever les lentes de la tige pilaire. Nous avons développé une méthode objective pour mesurer la force nécessaire d’enlever des lentes d’un poil humain. Une version améliorée de cette méthode nous a permis d’évaluer et de comparer l’efficacité de plusieurs produits pour éliminer les lentes. De l’eau désionisée, une application courte d’un produit commercial pour enlever des lentes et un baume ordinaire, réduisaient la force nécessaire pour enlever des poux. Une application prolongée d’un baume ordinaire ou d’un produit commercial facilitait spectaculairement l’élimination des lentes mais il n’y avait pas de différence entre le produit commercial et le baume ordinaire. Des ingrédients spéciaux comme l’acide formique n’apportaient pas un effet bénéfique additionnel.

Finalement, pour contrôler la pédiculose, une politique qui implique toute la communauté doit être développée. Les parents, les enseignants, les infirmières de l’école, la direction de l’école, les pharmaciens, les médecins, les autorités locales autant que le gouvernement central : tous jouent un rôle important.

La recherche scientifique sur la gale est confrontée avec des difficultés similaires à la recherche sur la pédiculose. En premier lieu, le diagnostic de la gale est basé sur une évaluation de l’anamnèse du patient et les lésions cliniques. Des techniques diagnostiques et des tests de laboratoire n’apportent pas un grand aide pour le clinicien. La difficulté d’établir le diagnostic de la gale est peut être une des raisons pour lesquelles il existe si peu d’études sur l’épidémiologie de la gale. En plus, ces études ne sont souvent pas représentatives pour la population belge.

Une étude prospective sur l’incidence de la gale à Gand était organisée en 2004 pour explorer les caractéristiques des patients souffrant de la gale. On a noté une incidence élevée chez des personnes âgées de plus de 65 ans. Ceci peut refléter un problème croissant de la gale dans les maisons de repos. On a aussi constaté une incidence élevée chez des immigrants. Dans le dernier cas, la nationalité est plutôt un indicateur de la position socio-économique des immigrants ayant une position plus modeste.

Cette étude suggérait aussi qu’un malade sur quatre doive visiter plusieurs médecins avant que le traitement approprié soit prescrit.

En ce qui concerne le traitement de la gale, l’évidence sur lequel l’avis du traitement doit être basé est plutôt limitée. Les études cliniques et les revues systémiques sont
compliquées par des problèmes de diagnostic et de méthodologie. Toutefois, les experts ont agréé plus au moins que pour l’instant la crème à la perméthrine est le traitement du choix. D’autres agents thérapeutiques comme la lotion au benzoate de benzoyle ou la crème au crotamiton sont moins efficaces. Ces produits peuvent toutefois être utiles dans le traitement, par exemple quand le coût d’un traitement est un problème.

Des études récentes ont démontré que l’ivermectine a des caractéristiques scabicides. Le rôle de ce produit dans l’approche de la gale n’est pas encore tout à fait éclairci parce que seule une étude a comparé l’efficacité de l’ivermectine avec la crème à la perméthrine dans une population où la gale est endémique. Toutefois, l’ivermectine est une bonne alternative quand un traitement systémique est préféré. Finalement, on a aussi discuté l’approche globale du traitement de la gale. Une directive basée sur des données évidentes est en cours de développement.

D’un point de vue général on peut poser comme principe qu’une connaissance suffisante d’une maladie est un préalable nécessaire pour pouvoir mener une approche de traitement adéquate.

Une étude sur la connaissance et le traitement de la gale chez des généralistes et dermatologues dans la région de Gand a démontré que la connaissance des deux groupes était d’un niveau acceptable. La connaissance semblait être meilleure chez des médecins avec plus d’expérience. Les résultats relativement bons semblent en contradiction avec les résultats de l’étude épidémiologique décrite plus haut. Dans cette étude, quasiment un patient sur quatre devait consulter plusieurs médecins avant que le traitement approprié soit prescrit. C’est possible que le résultat du test sur la connaissance soit trop optimiste. Cependant, cette discordance pouvait aussi indiquer que les médecins ont des problèmes pour mettre leur connaissance en pratique.

La recherche décrite dans cette thèse de doctorat a augmenté la connaissance sur quelques aspects dans l’approche thérapeutique de la gale et de la pédiculose. Toutefois, il y a toujours des issues qui restent non définies et qui demandent plus de recherche. En plus, des consensus internationaux sur les principes diagnostiques, épidémiologiques et thérapeutiques sont nécessaires pour améliorer l’approche et la politique à mener des deux maladies.
Part VII Research Papers
Paper 1:
Diagnostic value of screening methods for head lice.

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Submitted.
Diagnostic Value of Screening Methods for Head Lice

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Abstract

Objectives. *Pediculosis capitis* is a common infectious disease in schoolchildren. It is diagnosed when a living, moving louse is found. There are different methods to detect head lice but there is little information on the accuracy of the different screening methods. The objective of this study is to compare the diagnostic performance and efficiency of wet combing with conditioner (WCWC), dry combing (DC) and visual inspection (VI) as methods to detect head lice.

Patients & Methods. 608 children between 2 and 14 years of age attending primary schools and kindergartens in Ghent, Belgium were screened on the same day with VI, DC and WCWC consecutively by 3 different, blinded screening teams. All positive diagnoses were corroborated by an expert.

Results. The sensitivity of WCWC is 1.25 (P = 0.002, \( \chi^2 = 9.49 \)) higher than of DC and 2.47 (P < 0.001; \( \chi^2 = 59.07 \)) times higher than of VI. The sensitivity of DC is 1.98 times (P < 0.001; \( \chi^2 = 33.97 \)) the sensitivity of VI. With one set of permanent equipment, 33, 25 and 17 children can be screened a day with respectively VI, DC and WCWC. In this study, the costs per screened child were 57% higher with WCWC than with DC. The costs per detected case were 26% higher with WCWC than with DC.

Conclusion. WCWC has a higher diagnostic performance than DC and VI but more expenses and human resources are needed. If the necessary resources are available, WCWC should be advocated. DC is the next best alternative when WCWC is not possible. VI should be abandoned.
Introduction

*Pediculosis capitis* is a very common infectious disease in children. There is much confusion about the way pediculosis should be diagnosed. Nits, the eggshells of the head louse, can be present in case of an active infestation. However they are difficult to remove and can remain in the hair for a long time, even after a successful treatment.\(^1\) Nits in absence of lice is therefore a sign of a passive infestation. An active infestation is diagnosed when a living louse is found.\(^2\) The traditional method to detect lice is visual inspection (a visual check of the scalp while parting the hair by hand or with applicator sticks).\(^3\) Screening methods using a fine-toothed comb\(^4,\) conditioner (applied on dry, wet or shampooed hair\(^5-7\)) or a pediculicide\(^8\) \(^9\) have been used in the past two decades. Several authors have discussed the treatment of pediculosis\(^10-16\) but only two trials reported on the diagnostic accuracy of these screening methods. Mumcuoglu et al. demonstrated that dry combing (DC) was four times more effective than visual inspection (VI)\(^4\) and De Maeseneer et al. found that VI resulted in 30% false positives and 10% false negatives compared to wet combing with conditioner (WCWC).\(^17\) To our knowledge there are no published trials comparing WCWC to DC yet. There is currently no gold standard for the detection of head lice.\(^2,18\) The aim of this study is to compare the diagnostic performance of VI, DC and WCWC in the screening for head lice. Furthermore, the economic implications of the different screening methods are considered.
Patients & Methods

Enrolment of participants
Ghent is a Western European town where almost all children between the ages of 2.5 and 12 attend kindergartens or primary schools. The School Health Departments (SHD) in the Ghent area were asked to suggest four schools (2 with probably low, and 2 with probably high prevalence of head lice) that might be interested in participating in the study.
All children from these 4 kindergartens and primary schools were invited to join the screening programme. A letter was sent to all parents to inform them about the programme and to ask for their written consent.

Recruitment of screeners
About 50 volunteers, SHD staff, medical and nursing students with little or no prior experience, participated in the screening. In one school, parents helped with administrative functions. All volunteers attended an information session in which the study protocol was explained and the different screening methods were demonstrated. All volunteers rotated between the different teams.

Study protocol
Every participating child was first examined by VI, then by DC and finally WCWC. The three methods were applied consecutively by three independent screening teams. The screening teams were located in three separate rooms and blinded for the results of the other teams. The results of VI and DC were not communicated to the child.
First, hairpins and pony-tails were removed from the hair. In VI the screener lifted every lock of hair to carefully check the scalp for head lice, starting on one side of the head and working systematically up to the other side of the head. No tools were used, except for a magnifying glass. For DC, every screener used a set of combs (an ordinary wide-toothed comb and a fine-toothed comb (1998 Bug Buster comb)), a magnifying glass, wooden tooth picks and a small tray with disinfectant. After untangling the hair with the wide-toothed comb, the scalp was systematically combed lock by lock using the fine-toothed comb while gently touching the scalp. The comb was checked for lice after every stroke. Any louse found was double-checked by an expert (P.I.) and was left in the hair in order not to influence the performance of WCWC. When the screening was completed, the comb was cleaned with the toothpick and disinfected.
The screening protocol was concluded with a WCWC session. The same instruments as in DC, as well as conditioner, lukewarm water, kitchen roll and mobile washing basins were
made available to the screeners. After thoroughly wetting the hair, plenty of conditioner was applied to the hair. The hair was straightened and untangled with the wide-toothed comb. Then the hair was combed lock by lock from the nape of the neck to the forehead with the fine-toothed comb while remaining in contact with the scalp. After each stroke, a piece of kitchen roll was used to wipe off the conditioner in which the lice were caught. The conditioner was rinsed from the hair when the complete scalp surface was combed. Then the combing procedure was repeated from front to back. Any louse found was double-checked by an expert.

The time of the screening procedure was registered using a stopwatch. Time started running as soon as the screening was initiated and ended when the first living, moving louse was found or when the procedure was completed in the absence of lice.

The cost to screen a child was estimated per method. The estimation was based on the cost for material that is strictly needed to perform the screening such as combs, towels, conditioners, washing basins et cetera. Costs for tap water, material needed for administration or the laundering of towels was not included. The cost for personnel was not included because large scale screenings are usually performed by a variable number of professionals, assisted by many volunteers. The costs for consumables and permanent equipment were calculated per screened child and per detected case.

Each Screener filled out a form with the child’s hair colour (fair, brown or black), hair type (straight, curly or frizzy), hair length (very short, short, medium length, long), the result of the screening (louse yes/no, nit yes/no) and the time needed to complete the screening or to find the first living louse.19

All parents received a letter with the result of the screening, a free louse comb and a leaflet explaining different treatment options. Positive children were checked 10 days after the baseline screening using WCWC.

This study was approved by the ethics committee of the University Hospital Ghent (2004/409).

**Description of the statistical methods**

All positive results were double-checked by an expert to avoid false positive diagnoses. Since all positive test results were confirmed cases of pediculosis, the specificity of each method used in this study was by definition 100%. Moreover, the sensitivity of each method can be expressed as the ratio of the prevalence of lice as detected by that method (numerator) and the true prevalence (denominator). Hence, under these particular circumstances, comparing sensitivities of screening methods is equivalent to comparing their detection rates. The
McNemar test was used to compare related samples; the Kruskal-Wallis test was used to compare independent samples.
The threshold for statistical significance was chosen as \( \alpha = 0.05 \). Data were analyzed using SPSS (version 11.0).
Results

Demographic characteristics
A total of 732 children from four schools were invited to participate in the screening, which took place from September 26th to November 18th, 2005. Six hundred and eight children (83%) met the inclusion criteria and were screened by all 3 methods as described in the study protocol (see Fig 1).

Forty-four percent of the screened children were girls and 56% were boys. Children were between 2 and 14 years old with an average age of 8.5. The demographic characteristics are summarized in Table 1.

Detection of head lice
Head lice were found in 7.6%, 15.0% and 18.8% of the children with respectively VI, DC and WCWC. Nits in the absence of lice were found in 17.9%, 9% and 8.1% with respectively VI, DC and WCWC.

Fifty-one cases (40%; 95% confidence interval: 36.1%-43.9%) and 72 cases (55%; 95% confidence interval: 51%-59%) were missed with VI if respectively DC and WCWC were chosen as reference test. With DC at least 37 cases (29%; 95% confidence interval: 25.4%-32.6%) are missed compared to WCWC. As shown in the Venn diagram, WCWC resulted in 14 (11%; 95% confidence interval: 8.5%-13.5%) false negative diagnoses (Fig 2).

The true prevalence of head lice is at least 21% because 18.8% was detected by WCWC and another 2.3% was positive with DC alone. If the true prevalence would actually be 21%, then the sensitivity of VI, DC and WCWC would be 36% (95% confidence interval: 27.7%-44.3%), 71% (95% confidence interval: 63.1%-78.9%) and 89% (95% CI 83.6%-94.4%) respectively. The sensitivity of WCWC is 1.25 (P = 0.002, $\chi^2 = 9.49$) and 2.47 (P < 0.001; $\chi^2 = 59.07$) times higher than the sensitivity of respectively DC and VI. The sensitivity of DC is 1.98 (P < 0.001; $\chi^2 = 33.97$) times higher than in VI.

Is the performance of the screening method influenced by hair characteristics?
The detection rate of head lice is highest with WCWC in every category of sex, age, hair length, hair type and colour. The sensitivity of WCWC in brown hair is 3.3 (P < 0.001; $\chi^2 = 37.03$) times higher than in VI whereas in fair hair it is 1.6 (P = 0.001, $\chi^2 = 11.2$) times higher (Table 1).
**Time needed to screen**

The median time to screen a child without head lice using VI, DC and WCWC was respectively 2'46", 3'10" and 5'31" (P < 0.001, Kruskal-Wallis test $\chi^2 = 325.62$, df 2). The median time needed to detect head lice with VI, DC and WCWC was respectively 2'54", 2'02" and 3'34" respectively (P < 0.001, Kruskal-Wallis test $\chi^2 = 42.33$, df 2) (fig 3).

**Cost balance**

With one set of permanent equipment, 33, 25 and 17 children could be screened per day with respectively VI, DC and WCWC. If the permanent equipment is used all of the available time (182 days of school per year), 6006, 4550 and 3094 children can be screened per year with respectively VI, DC and WCWC. One set of equipment can be used for approximately 4 years before it needs to be replaced. The cost for permanent equipment per 100 children was calculated as the cost for one set of equipment divided by the number of children that could be screened with this equipment during a 4 year period. For instance, one set of permanent equipment for WCWC costs € 92.13. The cost for permanent equipment in WCWC was €92.13 divided by 12376 and is thus € 0.0075 per child or € 0.75 per 100 children. The total cost per 100 detected cases was calculated by dividing the total costs (permanent equipment and consumables) by the prevalence rate with this method. For instance if the total cost to screen 100 children with WCWC was € 26.34, than the total cost per 100 detected cases was € 26.34 divided by 18.8% or €140 per 100 detected cases and €1.40 per detected case.

In daily practice, the equipment will probably be used less frequently and the cost per screened child and detected case is also calculated in case the equipment is used half of the available time. (Table 2)

**Results of the screening 10 days post base-line**

At base-line screening, head lice were found in a total of 128 children. In 94 children (73%) a follow-up screening using WCWC was performed 10 days post base-line. Living, moving head lice were still found in 66 (70 %) children.
Discussion

To our knowledge this is the first study comparing the diagnostic accuracy of three commonly used screening methods in a single sample of 608 children. This report is unique because WCWC and DC have been compared directly. The sensitivity of WCWC was 1.25 times higher than the sensitivity of DC. In every category of hair length, colour and type, the highest detection rates were found with WCWC implying that this method performs best, regardless of the hair characteristics.

These results show that WCWC has the highest diagnostic accuracy. It should be noted that these results are applicable for WCWC as described in this paper. The results might be different in other variants (e.g. when applying conditioner to dry hair or combing wet hair without using conditioner) or in Bug Busting where conditioner is applied on shampooed hair. Fourteen cases were detected by DC or VI but not by WCWC. This might be indicative of method failure. It is also possible that lice were accidentally dislocated when manipulating the hair during the first two screenings. In this case the sensitivity of WCWC would be underestimated.

The sensitivity of DC is 2 times higher than the sensitivity of VI. This study confirms the results from the study by Mumcuoglu et al., who found that dry combing was almost 4 times more efficient. The time to find a louse was much shorter in the latter study, probably because the screeners were trained parasitologists. WCWC performed better than VI, which is in accordance with the study by De Maeseneer et al. In the latter, 10% false negatives were found with VI, which is much lower than in the current study. The accuracy of VI is clearly influenced by hair colour and the method performs better in blond hair. Our hypothesis is that the contrast between a louse and the background is much greater in fair hair than in brown hair, making them easier to spot in light-coloured hair.

The sensitivity of the three methods is estimated at 36%, 71% and 89% for respectively VI, DC and WCWC. The prevalence of lice, as estimated by combining all three methods, is at least 21% in this sample, which is higher than in some studies but comparable to prevalences found in others. However, the true prevalence in this sample is not known and might be higher if some cases are missed by all three methods. In that case the sensitivity of all three methods would be lower. For instance if the true prevalence were 25%, the sensitivity of the three methods would decrease to 30%, 60% and 75% respectively.

It should be noted that the diagnostic accuracy also depends on the skills of the screener, regardless of the chosen method. In this study, the screeners had limited prior experience but
received a short training, reflecting a real-life setting. The sensitivity of all methods would be lower if the screening were to be performed by an untrained screener.

Living lice were still found in 70% of the children screened 10 days post-baseline, illustrating that screening and written treatment advice are not sufficient to reduce the number of infested children. A coordinated approach with practice sessions and discussion groups actively involving the parents are probably needed.

The positive predictive value of the methods cannot be estimated because the experts who confirmed the positive diagnoses did not record false positive diagnoses. The characteristics of the infestation were not registered for pragmatic reasons. This could be an interesting factor that might influence the performance of a screening method and needs further investigation. However, since the methods were performed on the same population this will not have significantly influenced the main conclusion of this paper.

When choosing a diagnostic method, the economic consequences should be taken into consideration. VI is by far the least expensive method but is also the least accurate. Choosing WCWC implies more expenses and human resources than DC. The costs to screen a child are 57% higher with WCWC than with DC. The costs per detected case are 26% higher in WCWC than in DC. However it should be noted that the costs for permanent equipment can be lowered if children are combed over a sink instead of a hairdresser’s mobile washing basin.

Accurate detection is the cornerstone of head lice management and we therefore suggest that the most accurate detection method should be used. WCWC can be performed at home and even in schools where there is access to lukewarm water, but it is more expensive and time consuming than DC. Since the sensitivity of DC is two times higher than the sensitivity of VI, DC is the next best method if the appropriate conditions for WCWC are not available. VI should be abandoned since more accurate alternatives are available. Regardless of the chosen method it is important to give the screeners proper training to avoid false positive and false negative diagnoses. An expert should be available to assist in the diagnosis.

More studies on diagnostic accuracy of screening methods for head lice should be performed in experimental conditions and in real life situations in order to find a gold standard. In the meantime we suggest WCWC as the gold standard for detection of head lice in scientific studies until a more accurate method is found.
Acknowledgements.

We thank all children, parents, schools, SHD staff and volunteers who participated in the project.

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Prof. Dr. L. Annemans made valuable suggestions for the economic evaluation.
References


8. Meinking TL, Vicaria M, Eyerdam DH, Villar ME, Reyna S, Suarez G. Efficacy of a reduced application time of ovicide lotion (0.5% malathion) compared to nix creme rinse (1% permethrin) for the treatment of head lice. *Pediatric Dermatology* 2004;21(6):670-674.


Figures

Figure 1: Inclusion of participants

Eligible patients
(n = 732)

Excluded patients (n = 101)
Reasons:
- No consent from parents (n = 67)
- Child was absent (n = 33)
- Child refuses cooperation (n = 1)

Visual inspection
(n = 631)

Positive
(n = 31)

Negative
(n = 480)

Dry combing
(n = 569)

Wet combing
(n = 511)

Positive
(n = 41)

Negative
(n = 10)

Dry combing
(n = 46)

Wet combing
(n = 40)

Positive
(n = 46)

Negative
(n = 52)

Method skipped (n = 1)

Child refuses cooperation (n= 5)
Method skipped (n = 1)

Wet combing
(n = 6)

Wet combing
(n = 40)

Positive
(n = 40)

Negative
(n = 6)

Method skipped (n = 3)

Child refuses cooperation (n= 2)
Hair could not be combed (n= 11)
Method skipped (n = 3)

Visual inspection
(n = 631)

Positive
(n = 46)

Negative
(n = 585)

Dry combing
(n = 569)

Wet combing
(n = 51)

Positive
(n = 51)

Negative
(n = 511)
Figure 2: Venn diagram of the 128 true positive results according to visual inspection, dry combing and wet combing. (n=608)
Figure 3:

A) Time needed to complete the screening in the absence of lice

B) Time needed to find the first louse.
Tables

Table 1 Results of the screening with different methods: percentages (numbers) with head lice

<table>
<thead>
<tr>
<th></th>
<th>Number of children</th>
<th>Visual inspection</th>
<th>Dry combing</th>
<th>Wet combing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School (n=608)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School 1</td>
<td>165</td>
<td>5.5 (9)</td>
<td>13.3 (22)</td>
<td>17.6 (29)</td>
</tr>
<tr>
<td>School 2</td>
<td>102</td>
<td>13.7 (14)</td>
<td>28.4 (29)</td>
<td>30.4 (31)</td>
</tr>
<tr>
<td>School 3</td>
<td>174</td>
<td>8.6 (15)</td>
<td>14.4 (25)</td>
<td>23.6 (41)</td>
</tr>
<tr>
<td>School 4</td>
<td>167</td>
<td>4.8 (8)</td>
<td>9.0 (15)</td>
<td>7.8 (13)</td>
</tr>
<tr>
<td><strong>Sex (n=608)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy</td>
<td>340</td>
<td>1.8 (6)</td>
<td>7.9 (27)</td>
<td>12.1 (41)</td>
</tr>
<tr>
<td>Girl</td>
<td>268</td>
<td>14.9 (40)</td>
<td>23.9 (64)</td>
<td>27.2 (73)</td>
</tr>
<tr>
<td><strong>Age (years) (n=608)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 5</td>
<td>76</td>
<td>9.2 (7)</td>
<td>17.1 (13)</td>
<td>22.4 (17)</td>
</tr>
<tr>
<td>6-7</td>
<td>141</td>
<td>7.1 (10)</td>
<td>14.2 (20)</td>
<td>16.3 (23)</td>
</tr>
<tr>
<td>8-9</td>
<td>152</td>
<td>7.9 (12)</td>
<td>16.4 (25)</td>
<td>21.1 (32)</td>
</tr>
<tr>
<td>10-11</td>
<td>160</td>
<td>5.0 (8)</td>
<td>13.1 (21)</td>
<td>14.4 (23)</td>
</tr>
<tr>
<td>≥ 12</td>
<td>79</td>
<td>9 (11.4)</td>
<td>15.2 (12)</td>
<td>24.1 (19)</td>
</tr>
<tr>
<td><strong>Hair length (n=605)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very short</td>
<td>155</td>
<td>2.6 (4)</td>
<td>9.7 (15)</td>
<td>14.2 (22)</td>
</tr>
<tr>
<td>Short</td>
<td>229</td>
<td>3.1 (7)</td>
<td>10.9 (25)</td>
<td>15.7 (36)</td>
</tr>
<tr>
<td>Medium</td>
<td>89</td>
<td>18.0 (16)</td>
<td>24.7 (22)</td>
<td>24.7 (22)</td>
</tr>
<tr>
<td>Long</td>
<td>132</td>
<td>14.4 (19)</td>
<td>22.0 (29)</td>
<td>25.8 (34)</td>
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<tr>
<td><strong>Hair type (n=608)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>552</td>
<td>8.2 (45)</td>
<td>15.9 (88)</td>
<td>19.4 (107)</td>
</tr>
<tr>
<td>Curly</td>
<td>43</td>
<td>2.3 (1)</td>
<td>7.0 (3)</td>
<td>16.3 (7)</td>
</tr>
<tr>
<td>Frizzy</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Hair colour (n=603)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>121</td>
<td>0.8 (1)</td>
<td>2.5 (3)</td>
<td>8.3 (10)</td>
</tr>
<tr>
<td>Brown</td>
<td>242</td>
<td>7.0 (17)</td>
<td>18.2 (44)</td>
<td>23.1 (56)</td>
</tr>
<tr>
<td>Fair</td>
<td>240</td>
<td>11.7 (28)</td>
<td>17.9 (43)</td>
<td>19.2 (46)</td>
</tr>
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</table>
Table 2 Costs of VI, DC and WCWC per screened child and per detected case.

<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment</th>
<th>Cost per 100 children screened (€)</th>
<th>Cost per detected case (€)</th>
<th>Cost per 100 children screened (€)</th>
<th>Cost per detected case (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual inspection</td>
<td>Permanent equipment: Magnifying glass</td>
<td>0.13</td>
<td>&lt; 0.01</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Consumables: /</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>0.13</td>
<td>&lt; 0.01</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td>Dry combing</td>
<td>Permanent equipment: Magnifying glass, ordinary comb, plastic tray</td>
<td>0.03</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumables: Fine toothed comb, disinfectant</td>
<td>16.74</td>
<td>16.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>16.77</td>
<td>1.11</td>
<td>16.81</td>
<td>1.12</td>
</tr>
<tr>
<td>Wet combing</td>
<td>Permanent equipment: Magnifying glass, ordinary comb, plastic tray, towels, washing basin</td>
<td>0.75</td>
<td>1.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumables: Fine toothed comb, disinfectant, kitchen role, conditioner</td>
<td>25.59</td>
<td>25.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>26.34</td>
<td>1.40</td>
<td>27.09</td>
<td>1.44</td>
</tr>
</tbody>
</table>
Paper 2:
The importance of socio-economic status and individual characteristics on the prevalence of head lice in schoolchildren

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Clinical report

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The study on which the manuscript is based has been subject to ethical review by the Ethics committee of the Ghent University Hospital, Chair: Prof. Dr. Rubens, 3P4, De Pinteelaan 185, 9000 Gent, Belgium

The importance of socio-economic status and individual characteristics of the prevalence of head lice in schoolchildren

Pediculosis is a common infestation in schoolchildren but little is known about the factors influencing its prevalence. The aim of this study was to determine the prevalence of head lice in schoolchildren in Ghent and to investigate the independent association between individual characteristics of the child, socio-economic status (SES) of the family and head lice. The prevalence of head lice baseline and 14 days after treatment advice was determined by the wet combing method in a total of 6,169 schoolchildren aged 2.5 to 12 years from a clinic in Ghent (Belgium). Age, sex, educational level and hair characteristics of the child, SES of the family, and number of children in the family was collected by the school health department. The prevalence of head lice was 8.9%. The only statistically significant factors at the child level are SES, the number of children in the family, hair length and hair colour. Treatment failure was recorded in 41% of the children positive at baseline screening and was significantly related to hair colour and SES. This study demonstrated that the prevalence of head lice is determined by clustering of children rather than by characteristics of the child. The management of head lice should take a community-based approach equally involving families, schools, health care professionals and the government.

Key words: head lice, wet combing, prevalence, socio-economic status

Pediculosis, which is defined as an infestation with head, body or crab lice, is a frequent occurring skin infestation [1, 2]. Especially, head lice (Pediculus humanus capitis) infestations are a common health problem mainly affecting schoolchildren aged between 3 and 12 [3]. Head lice infestation prevalence rates of 5.8% to 35% have been reported [3-8]. In Belgium, the only information concerning the prevalence of head lice in schoolchildren comes from a recent but small survey in two primary schools in the city of Ghent (an industrialised city in the northern part of Belgium, 226,083 inhabitants), revealing prevalence rates of 13.0% and 19.5% [9]. The origin of a head lice infestation is unclear. Most prevalence studies examine the relationship between personal characteristics of the child (i.e. sex, age, hair length, hair type) and infestation [3, 4, 7, 10], but there are few studies that also consider the family’s socio-economic status (SES) [6-8, 11]. All these studies have conflicting results that can be partly explained by the use of different diagnostic criteria, screening methods, the presence of confounding factors, and limited statistical techniques. In some studies, children are considered to be infected if either lice or nits are present [6, 8]. However, an active infestation should only be diagnosed when a living, moving louse is detected [12]. Furthermore, there are three methods of detecting head lice: visual inspection, inspection with a detection comb and wet combing. It has been demonstrated that the latter two are more accurate than the first [10, 13]. Wet combing is probably more accurate than dry combing because lice get stuck in the water and conditioner and are therefore more easily found. Although wet combing is time-consuming and laborious in comparison to other detection methods, it has been illustrated elsewhere that it is feasible to screen large groups of children with this method [9]. Apart from the differences in diagnostic methodology, there is also a large variation in the statistical methods applied. When analyzing this kind of data, statistical tests controlling associations between the different factors should be used. Therefore, the complex mechanisms of interaction between the multiple determinants of head lice are still unexplained. The objective of this study is to determine the prevalence of head lice in schoolchildren in Ghent, using the wet combing technique, and to investigate the independent association between individual characteristics of the child, socio-economic status and head lice.

Materials and method

Population and sample

The three School Health Departments (SHD) screen all schoolchildren yearly for head lice using dry inspection. In

* Both authors equally contributed to this paper.

2001, the SHD started a pilot project in which children were screened using the wet combing method. All kindergartens and primary schools in Ghent (174) were invited to participate in this pilot project, of which 30 agreed. Between January and June 2001, all children from the participating schools present on the day of the screening were included in the project. A total of 6,169 children were screened, representing 30% of the town's total population of children aged between 3 and 12.

Data collection

Several SHD staff screening teams were involved in the pilot project, led by a staff member trained in the wet combing method by experts on this subject. Where necessary, screening teams were reinforced with parents and teachers, who were trained using an educational package including a video of the wet combing method. The team leader double-checked positive results found by the team members. An ordinary shampoo, conditioner and a fine-toothed plastic comb (as in a Bug Buster kit) were used. First, the hair of the child was washed with an ordinary shampoo and plenty of conditioner was applied to the wet hair after straighthening with a grooming comb. Then the scalp was systematically combed with a fine-toothed comb, first from back to front and then vice versa. Combing was started at one side of the head and ended at the other side. When combing is used, lice get caught in the moisture and are unable to move. The fine-toothed comb lifts out lice from the hair, even the smaller nymphal stages that sometimes remain unnoticed by the naked eye.

A child was found positive if a living louse was found. The presence of nits was also recorded, but no distinction was made between viable or dead eggs or empty eggshells. The positive children were given a letter for their parents with treatment advice and were screened again two weeks later.

For every child, the SHD staff collected data about demographic characteristics (sex, date of birth, class and school), properties of the hair (length, colour and type) and characteristics of the family (number of children in the family and socio-economic status). Hair length was defined as very short (< 2 cm), short (≥ 2 cm but less than shoulder length), medium (≥ shoulder length) or long (> shoulder length). Hair colour was divided into 4 categories (black, brown, red or fair) (figure 1) and hair type into 3 categories (straight, curly or frizzy).

The socio-economic status of the family was based on the person with the highest occupational status in the household and retrieved from the children's school file. Occupation was classified according to the Standard Occupational Classification, published by the Office of Population Censuses and Surveys, using 4 categories: unemployed, manual worker, non-manual worker and professional [14].

The nationality of the child was also recorded but not included in the analysis since there were too many different nationalities and recording this information into a dichotomous variable (Belgium versus other) led to an important loss of data. All parents of positive children were given treatment advice and the treatment chosen was recorded for 25% of the positive children. No information was obtained on whether the treatment was applied correctly. Positive children were screened again 14 days after baseline screening. Results from the second screening are available for 87% of the children found to have lice at the baseline.

Statistical analysis

The data was analysed using SAS® release 8.02. First, two-dimensional crosstabs with chi-square test statistics and correlation matrices were built in order to study the bivariate relationships between the prevalence of head lice and the independent variables. Secondly, to determine the relative importance of the different variables in explaining or predicting the presence of head lice, the Glimmix macro written by Russ Wolfinger from SAS was used to construct a logistical model with random effects [15]. Since the sample design was typically hierarchical, this type of multilevel model was most appropriate for a dichotomous outcome variable because it incorporated the fact that observations from same subpopulations were more equivalent than observations from other ones. P < 0.05 was set as the level of statistical significance.

Results

The prevalence of head lice infestations in children from kindergartens and primary schools in Ghent was 8.9%. Another 4.6% had nits without lice, a sign of a past infestation.

Bivariate analysis demonstrated a significant association between head lice and the child's sex, educational level, hair length and colour, number of children in the family and SES (table 1).

Multilevel analysis showed that the variance at school level is 1.93 (P = 0.011). The same parameter at class level within schools is 2.58 (P < 0.001) and the residual level (level of the different children within classes) is 0.59 (P < 0.001).

This shows that a child's school and in particular his or her class have a greater impact on the risk of head lice than individual characteristics. The impact at child level can be attributed to SES (P = 0.017), the number of children in the family (P < 0.001), the length of the child's hair (P = 0.028) and the hair colour (P = 0.021) (table 2).

Being from a family with a lower SES, more children and having longer hair tend to result in a higher risk of getting head lice (respectively OR: 0.80-0.95 CI: 0.68-0.96; OR: 1.2,95% CI: 1.10-1.32; OR: 1.2, 95% CI: 1.02-1.43). For example, for every child that a family has, the probability

![Figure 1. Different hair colours. A) Fair hair, B) Black hair, C) Brown hair, D) Red hair.](image-url)
Table 1. Sex, age, educational level, hair characteristics, number of children in the family and socio-economic status (SES) of the family: bivariate results at baseline and two weeks after baseline screening

<table>
<thead>
<tr>
<th></th>
<th>Baseline screening</th>
<th>2 weeks after baseline screening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>%</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>6104 (48.1)</td>
<td>6.8 (&lt; 0.001)</td>
</tr>
<tr>
<td>Girls</td>
<td>5166 (51.9)</td>
<td>10.7</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 5</td>
<td>5519 (28.8)</td>
<td>0.194 (0.001)</td>
</tr>
<tr>
<td>6-7</td>
<td>1297 (23.5)</td>
<td>9.1</td>
</tr>
<tr>
<td>8-9</td>
<td>1252 (22.7)</td>
<td>9.2</td>
</tr>
<tr>
<td>10-11</td>
<td>1413 (25.6)</td>
<td>9.5</td>
</tr>
<tr>
<td>≥ 12</td>
<td>1136 (20.6)</td>
<td>7.0</td>
</tr>
<tr>
<td>Educational level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kindergarten</td>
<td>1619 (26.8)</td>
<td>10.2</td>
</tr>
<tr>
<td>1st and 2nd year of primary school</td>
<td>1778 (29.4)</td>
<td>9.7</td>
</tr>
<tr>
<td>3rd and 4th year of primary school</td>
<td>1553 (25.7)</td>
<td>8.0</td>
</tr>
<tr>
<td>5th and 6th year of primary school</td>
<td>1090 (18.0)</td>
<td>6.1</td>
</tr>
<tr>
<td>Hair length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very short</td>
<td>1329 (21.7)</td>
<td>5.1</td>
</tr>
<tr>
<td>Short</td>
<td>2218 (36.2)</td>
<td>6.5</td>
</tr>
<tr>
<td>Medium</td>
<td>1336 (21.8)</td>
<td>11.5</td>
</tr>
<tr>
<td>Long</td>
<td>1241 (20.3)</td>
<td>10.6</td>
</tr>
<tr>
<td>Hair type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>592 (38.5)</td>
<td>8.6</td>
</tr>
<tr>
<td>Curly</td>
<td>785 (12.9)</td>
<td>10.6</td>
</tr>
<tr>
<td>Frizzy</td>
<td>99 (1.6)</td>
<td>8.1</td>
</tr>
<tr>
<td>Hair colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palt</td>
<td>2137 (34.9)</td>
<td>7.7</td>
</tr>
<tr>
<td>Red</td>
<td>121 (2.0)</td>
<td>9.1</td>
</tr>
<tr>
<td>Brown</td>
<td>2808 (45.8)</td>
<td>10.2</td>
</tr>
<tr>
<td>Black</td>
<td>1062 (17.3)</td>
<td>8.2</td>
</tr>
<tr>
<td>Number of children in family</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>948 (15.9)</td>
<td>7.8</td>
</tr>
<tr>
<td>2</td>
<td>2580 (43.3)</td>
<td>7.6</td>
</tr>
<tr>
<td>3</td>
<td>1499 (25.2)</td>
<td>8.6</td>
</tr>
<tr>
<td>≥ 4</td>
<td>916 (15.6)</td>
<td>13.9</td>
</tr>
<tr>
<td>SES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>296 (7.9)</td>
<td>13.5</td>
</tr>
<tr>
<td>Manual worker</td>
<td>1570 (42.0)</td>
<td>12.4</td>
</tr>
<tr>
<td>Non-manual worker</td>
<td>1490 (39.8)</td>
<td>5.8</td>
</tr>
<tr>
<td>Professional</td>
<td>386 (10.3)</td>
<td>5.2</td>
</tr>
</tbody>
</table>

The prevalence of head lice infestation in a large sample of schoolchildren in Ghent was 8.9%, lower than the previously reported 13.0% and 19.5% from a previous small study in the town. The schools in the latter study were selected because of their high motivation, which was probably related to the fact that they have encountered head lice before. The multilevel analysis shows that clustering of children in groups (in classes and schools) is the most important factor determining the risk of head lice. Head lice are transmitted by head-to-head contact and probably also by fomites [16]. Children from the same class have intense contact with each other, providing frequent opportunities to transmit head lice. However individual characteristics do have some impact: hair length, hair colour, the number of children in the family and socio-economic status of the family are statistically significant associated with the prevalence of head lice.

Discussion

The prevalence of head lice infestation in a large sample of schoolchildren in Ghent was 8.9%, lower than the previously reported 13.0% and 19.5% from a previous small study in the town. The schools in the latter study were selected because of their high motivation, which was probably related to the fact that they have encountered head lice before. The multilevel analysis shows that clustering of children in groups (in classes and schools) is the most important factor determining the risk of head lice. Head lice are transmitted by head-to-head contact and probably also by fomites [16]. Children from the same class have intense contact with each other, providing frequent opportunities to transmit head lice. However individual characteristics do have some impact: hair length, hair colour, the number of children in the family and socio-economic status of the family are statistically significant associated with the prevalence of head lice.

The strength of this study is its methodology. No similar survey applying the same diagnostic criteria and screening
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Table 2. Multilevel analysis at baseline screening and two weeks after baseline screening

<table>
<thead>
<tr>
<th>Base line screening</th>
<th>14 days after baseline screening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
</tr>
<tr>
<td>School-level</td>
<td>1.933</td>
</tr>
<tr>
<td>Class-level</td>
<td>2.581</td>
</tr>
<tr>
<td>Child-level</td>
<td>0.594</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odds ratio (95% CI)</th>
<th>P-value</th>
<th>Odds ratio (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1.3 (0.89-1.82)</td>
<td>0.187</td>
<td>0.9 (0.37-2.33)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.9 (0.91-1.07)</td>
<td>0.859</td>
<td>1.0 (0.89-1.20)</td>
</tr>
<tr>
<td>Hair length</td>
<td>1.2 (1.02-1.43)</td>
<td>0.028</td>
<td>1.3 (0.80-2.00)</td>
</tr>
<tr>
<td>Hair type</td>
<td>Straight</td>
<td>1.5 (0.51-4.30)</td>
<td>0.465</td>
</tr>
<tr>
<td></td>
<td>Curly</td>
<td>1.6 (0.55-4.84)</td>
<td>0.376</td>
</tr>
<tr>
<td></td>
<td>Frizzy</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Hair colour</td>
<td>Fair</td>
<td>0.9 (0.75-1.27)</td>
<td>0.861</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>0.4 (0.14-1.37)</td>
<td>0.155</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>0.6 (0.44-0.89)</td>
<td>0.008</td>
</tr>
<tr>
<td>Number of children in family</td>
<td>1.2 (1.10-1.32)</td>
<td>&lt; 0.001</td>
<td>1.1 (0.92-1.40)</td>
</tr>
<tr>
<td>Sex</td>
<td>0.8 (0.68-0.96)</td>
<td>0.011</td>
<td>0.6 (0.34-0.95)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.01 (0.01-0.16)</td>
<td>0.003</td>
<td>0.4 (0.01-10.2)</td>
</tr>
</tbody>
</table>

Method and including a comprehensive set of confounding factors has ever been performed on such a large sample. Furthermore, the use of multilevel analysis allowed the unique impact of each independent variable to be determined. A source of concern in the present study could be the lack of a randomised sample. However, a good representative sample of the population was achieved with only a slight overrepresentation of larger kindergartens and primary schools. Furthermore, the prevalence might be influenced by seasonal trends in head lice infestations as this study was carried out between January and June. Some authors found a difference in prevalence according to the month when a screening was performed [17, 18]. Finally, information on SES was not always recorded in detail in the child’s school record, resulting in a loss of data.

This study confirms the results of other studies in the field, yet on some points it nuances, refutes or explains earlier findings. The clustering of head lice within classes was observed in a prevalence study on 735 pupils from one school [4]. Our study, performed on a larger sample of children from different schools, confirms the observation of the latter study. Concerning hair characteristics, as reported earlier by Muneuoglu et al. [3], we found higher prevalence rates in children with brown hair. One can assume that brown-coloured lice contrast more in fair, red and black hair and are therefore detected earlier. Earlier treatment of these children may lead to lower prevalence at formal cross-sectional screening sessions. Hair length can probably be considered as an important transmitting factor, as head lice need specific conditions to move from one head to another [16], which occur more frequently in longer hair. It also seems that the infestation rate rises with the number of children in the family, possibly because children in large families have a higher risk of being infected by their siblings (or parents). The influence of the family’s socio-economic status on the presence of head lice has been investigated before, using indicators such as educational level or profession of the parents, family income, recourse to social security and socio-economic class of the school. A positive correlation has been found [1, 6, 11, 19] in some reports but not in others [17, 18]. However, in most surveys, only bivariate analysis has been used. This study shows that when adjusting for a range of confounding factors, SES (defined as the highest occupational class in the household) is significantly related to the prevalence of head lice. In several studies, a difference was found in prevalence rates between girls and boys [1, 4, 6, 7, 20]. It is believed that gender-related behaviour differences affect transmission rates, e.g. difference in personal grooming, close contact, hairstyle changes and the use of hair accessories [21]. Counahan et al. supported the gender difference based on a large study that used multilevel statistical techniques and included type of residence, class, gender and hair length as confounding factors [20]. However, when building a model that adjusts to a more detailed set of determinants including other hair characteristics, no difference was found. We found that the commonly assumed risk factor of age was not associated with active infestation [6, 10]. Probably, this could be explained by the high association with school class which was introduced as a level in the model. This study did not confirm earlier findings of lower infestation rates in children with curly hair [5]. Nymphal stages are easily missed in curly or long hair when using the dry inspection method, possibly leading to an underestimation of head lice infestation in children with curly or long hair [22]. When applying wet combing, even the small lice are found in straight as well as in curly hair [23].

A striking result from the screening after treatment advice is that 41.4% of the children found to be positive in the baseline screening were still positive, meaning they were not adequately treated. This is rather high, considering that every parent received treatment advice. Vander Stichele et al. also found a low treatment effectiveness of 51% [9]. Several factors could be responsible for the high rate of
treatment failure. It cannot be excluded that some parents, regardless of the advice given, did not treat their children. It is more likely, however, that there was resistance to the chosen pediculicide or that a lot of children were not treated correctly. Pediculicides are often expensive and should be applied correct in order to have optimum results. The wet combing method was also discussed as a treatment option. This method is relatively cheap but requires stringent implementation and is time-consuming. Wet combing should be repeated meticulously once every 3 to 4 days over a period of 14 days to break the life cycle of the head louse [9] and is not effective if the instructions are not followed correctly.

Attention should be paid when interpreting the results of this study. A significant association was found between head lice and several factors at child level, yet this does not imply a causal relationship. Presumably, these factors lead indirectly to higher prevalence rates because they hamper the detection (e.g. hair colour) or treatment (e.g. SES) of lice.

This study illustrated that the clustering of children in classes and schools is a more important determinant of the prevalence of head lice than personal characteristics. Head lice infection is therefore difficult to avoid, making its early detection and effective treatment all the more important. Although earlier studies indicated it was feasible to screen larger groups of children for head lice using the wet-combing technique, the feasibility of organising large screening campaigns in schools several times per year is questionable. Probably, it is more advisable to introduce screening in the daily routine of the family, e.g. as part of the weekly bathing ritual. Schools and school health departments could play an important supporting role for the parents by organising information campaigns and “practice sessions” on the screening and treatment of children.

The current study showed that children from families with a lower SES are particularly at risk of getting head lice. Previous studies showed that the lives of people from the lowest socio-economic classes are often characterised by a short-term “survival” perspective. “Compliance” is, from a socio-culturally point considered, a middle-class concept because in lower social classes, the need for an adequate follow-up of the treatment instructions could be overruled by acute social problems related to income, housing conditions... [24]. Therefore special emphasis should be put on the need to establish specific support systems (e.g. by school nurses and primary care nurses) for children from low SES families with lice infestations. As Whitehead has indicated, efforts to decrease social inequalities in health must adopt a multi-level approach and focus on empowering families, strengthening communities (by educational efforts towards caregivers) and encouraging macroeconomic and cultural change [25].

Further research is needed to confirm the findings of this study using a randomised sample and more detailed measurement scales, e.g. for SES. A cost-effectiveness study should be performed in which the benefits and costs of wet combing versus detection-combing of dry hair are assessed.

Acknowledgements. We would like to thank all staff members of the School Health Departments who collected the data, and the parents and children for their participa-

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Paper 3:
Method to measure force required to remove Pediculus humanus capitis (Phthiraptera: Pediculidae) eggs from human hair.

**Hilde Lapeere**, Lieve Brochez, Yves Vander Haeghen, Cyriel Mabilde, Robert Vander Stichele, Luc Leybaert, Jean-Marie Naeyaert.

SHORT COMMUNICATION

Method to Measure Force Required to Remove Pediculus humanus capitis (Phthiraptera: Pediculidae) Eggs from Human Hair

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ABSTRACT Head lice are very common and mainly affect children between 3 and 12 yr old. Little is known about the way nits, the eggs of the head louse, are attached to the hair. In this report, an objective measurement procedure for the ease with which nits can be removed is presented. The first peak force, associated with the start of nit movement, and the average and maximal force during the sliding of the nit were measured. The three force variables correlated with the length of the cylinder by which the nit was attached to the hair. A negative correlation was found between the maximum force exerted and the distance of the nit from the scalp. The method described in this report can be used to determine the in vitro efficacy of various products to remove nits.

KEY WORDS head louse, Pediculus, nit removal, louse infestation, eggs

Pediculus capitis is caused by the head louse, Pediculus humanus capitis (De Geer 1776). The prevalence of head lice is usually <10%, but in some regions one of every four children is infested (Gratz 1997, Downs 2000). Especially children between 3 and 12 yr old are affected. Treatments for head lice usually kill and remove lice, but dead or empty nits (eggs) remain firmly attached to the hair for several months. In addition to the cosmetic problem, nits are also responsible for confusion and false positive diagnoses when children are screened for head lice, leading to unnecessary treatments with pediculicides (William et al. 2001). In 25–30% of children attending kindergarten or primary school, nits are found in the absence of head lice (Muncucoglu et al. 1990, 2001).

Nits are firmly attached to the human hair shaft, usually close to the scalp. The female first produces a liquid substance (sometimes called “glue”), which is spread along the hair and the egg. After hardening of this substance, the hair and egg are surrounded by a sheath of solid material (Carter 1990). The part encircling the hair shaft is called the nit cylinder. The egg thus is mechanically attached to the hair and protected from outside influences. The egg will develop into a nymph that emerges ≈7 to 10 d after oviposition (Ibarra 1993).

Little is known about the exact composition of the glue. Electrophoresis of secretions from the female louse “glands has demonstrated the presence of four proteins (Carter 1990). The proteinaceous composition of the sheath has been confirmed by histochemical analysis and flash pyrolysis-gas chromatography (Burkhardt et al. 1999a, b). The exact nature of these proteins remains unknown, leaving us without a target for the development of new therapies.

There is very little information on how strongly a nit is attached to the hair and how nits can be removed (Burkhardt et al. 1999b, c). Several authors have suggested various products and protocols to remove nits (DeFelice et al. 1989, Burkhardt et al. 1998), but there is very little evidence to support their use. In this report, an objective procedure to measure the force needed to remove nits from human hairs is described.

Materials and Methods

Sample Collection. Hairs with nits were collected from infested children from 4 to 12 yr old (average 9 yr). Children either came to the Department of Dermatology (University Hospital, Ghent) or were seen during a 6-mo screening campaign in primary schools in Ghent, Belgium. The ethics committee of the University Hospital Ghent granted approval for this project. Sample hairs were cut as close to the scalp as possible. Only hairs with a single nit attached at least 17 mm from the proximal end of the hair were used, because hairs with nits closer to the proximal end could not be attached to the measuring device. Approximately 14% of the nits contained a dead egg, whereas the rest were empty. The distal end of the hair was cut 20 mm behind the nit. Hairs were stored for 2 wk to 6 mo at 22°C and 37% RH until they were used for experiments.
Basic Measurements of Hair and Nit Parameters. The diameter of the hair, the length of the nit cylinder, and the distance between the scalp end of the hair and the nit were measured. Hair diameter and nit cylinder length were determined from micrographs (at 10× magnification) by using a microscope (Axioskop, Carl Zeiss, Zaventem, Belgium) equipped with a digital camera (PL-A642, PoseLINK, Ottawa, Ontario, Canada) (Fig. 1). The distance of the nit from the scalp end of the hair roughly reflects the age of the nit. Nits located further away are usually older than nits close to the scalp (Muncuoglu 1990). The distance of the nit from the scalp cut side was determined with a ruler.

Measurements of Nit Removal Parameters. A small metal cylinder, 2 mm in length, was cut from a 30-gauge subcutaneous needle with an internal diameter of 0.23 mm (Terumo, Haasrode, Belgium). The metal cylinder was attached to a force transducer (FT03C, Grass Instruments, Quincy, MA). A hair with a nit was put with its scalp end through the small metal cylinder and was knotted to a bent needle connected to a surgical thread (Ethilon 7/0, Johnson & Johnson, New Brunswick, NJ) (Fig. 2). The surgical thread was wound several times around the axis of a slow-spinning electrical motor with integrated gear-box (Minimotor SA, Agno, Switzerland). The measurement procedure consisted of starting the motor, which caused the hair to move in the metal cylinder at a speed of ~125 mm/min. At the point where the nit was halted by the metal cylinder, force started to build up, until

Fig. 1. Photograph of a nit attached to a hair with the measured variables. (A) Length of the nit cylinder. (B) Diameter of the hair. (C) Distance of the nit from the scalp end side of the hair. (D) Distance of the nit to the distal end of the hair, cut at 20 mm.

Fig. 2. Diagram of the device to measure the force needed to remove a nit. The proximal end of the hair is slid through the metal cylinder that is attached to the force transducer. The proximal end is knotted to the bent needle of a surgical thread that is attached to the motor. The hair with the nit starts to slide through the metal cylinder when the motor is turned on. The metal cylinder holds the nit back, and the force to remove the nit is measured.
the nit cylinder lost grip on the hair and the hair began sliding through the immobilized nit. The nits were observed with a microscope (Wild, Heerbrugg, Switzerland) during the measurement and were photographed afterwards. They did not break or tear during the procedure.

The force from the force transducer was continuously recorded with a pen recorder (PMS222, Philips, Eindhoven, Holland). Force was a function of time and thus a function of the hair displacement. The force transducer was calibrated with standard weights (from 1 to 70 g) and displayed a linear response over the range tested, i.e., from 10 to 69 mN.

Plots of force as a function of time were analyzed, and the following parameters were determined: 1) the first peak in the plot (F_{\text{1st}}) corresponding to the moment at which the nit started to slide, 2) the average force (F_{\text{av}}) needed to displace the nit over a distance of 20 mm over the hair, and 3) the maximum force (F_{\text{max}}) that occurred during the whole procedure (Fig. 3). F_{\text{peak}} was directly measured from the recorded plots on recorder paper, whereas F_{\text{av}} and F_{\text{max}} were determined from scanned plots analyzed with software developed in Matlab (Mathlab 6.1, Mathworks Inc. 2001).

Statistical Analysis. Data were analyzed using SPSS software (SPSS Inc. 2001). All variables were checked for normality with a Q-Q plot and a Kolmogorov-Smirnov test. Nonparametric tests were used because most variables were not normally distributed. A Spearman’s rho correlation coefficient was calculated to investigate the correlation between the independent variables (diameter of the hair, length of the nit cylinder, and distance of the nit from the scalp) and the dependent variables F_{\text{av}}, F_{\text{peak}}, and F_{\text{max}}. The Kruskal-Wallis test was used to compare medians of multiple groups (Rosner 2000). The threshold for statistical significance was at P < 0.05.

Results

Basic Measurements of Hair and Nit Parameters. The diameter of the hair, the length of the nit cylinder, and the distance of the nit from the scalp end of the hair were measured in 104 hairs with attached nits taken from 18 different patients. The mean ± SEM hair diameter was 70 ± 1.2 μm, the mean ± SEM cylinder length 800 ± 32.2 μm, and the mean ± SEM distance of the nit from the scalp cut end was 49 ± 3.5 mm.

Only the diameter of the hair was normally distributed (Kolmogorov-Smirnov test and Q-Q plot), whereas the two other variables were not (Fig. 4). There were significant between-patient differences in the diameter of the hair and the distance of the nit from the scalp end (χ² = 28.012, df = 17, P = 0.045 and χ² = 19.262, df = 17, P = 0.023, respectively) but not in the length of the nit cylinder.

Precision of the Measuring Method. The precision of the measuring method was determined by using 10 pieces of surgical string (Ethilon, 6/0, Johnson & Johnson, New Brunswick) on which a piece of rubber (2 by 2 by 1.5 mm) was headed. The string was put through the center of each piece of rubber to obtain 10 similar structures mimicking a nit attached to a hair. Each piece of string was attached to the measuring device, and the piece of rubber was pulled along the thread. This was repeated three times per piece of string. From these measurements, the coefficient of variation, i.e., the standard deviation relative to the mean, was calculated as a measure of precision. The coefficient of variation was 3.1% for the measurement of F_{\text{peak}}, 6.8% for F_{\text{av}}, and 3.1% for F_{\text{max}}. This means that the proposed measurement method is very precise.

Force measurements on untreated hairs were compared with measurements on hairs soaked for 30 min in vinegar (7% acetic acid, pH 2.2, Meteor, Sint-Martinus, Roosdaal, Belgium) to explore whether the measurement method is capable of detecting differences in the strength of nit attachment. Vinegar was used because Burkhart et al. (1998) indicated it affected nit removal, and because it is a common “home remedy.” The diameter of the hair, the length of the nit cylinder, and the distance of the nit from the scalp did not differ between the two groups, but all nit removal parameters were significantly reduced in the treated group (data not shown). This illustrates that the measurement method is also able to detect differences in the strength by which a nit is attached.

Measurements of Nit Removal Parameters. Various parameters that describe the difficulty for sliding a nit from its initial fixed position over a distance of
move a nit depended on the patient from whom the hairs were taken, the diameter of the hair, the length of the nit cylinder, or the distance of the nit from the scalp end side of the hair. No correlation was found between the patient and the force parameters. A positive correlation was found between $F_{\text{peak}}$, $F_{\text{av}}$, and $F_{\text{max}}$ and the length of the nit cylinder (correlation coefficient, respectively, 0.214, 0.269, and 0.305 with $P = 0.039$ for $F_{\text{peak}}$, $P = 0.009$ for $F_{\text{av}}$, $P = 0.003$ for $F_{\text{max}}$). A negative correlation was found between $F_{\text{max}}$ and the distance of the nit from the scalp end side of the hair (correlation coefficient $-0.252$ and $P = 0.015$).

Figure 5 illustrates the correlation of the various force parameters with the length of the nit cylinder, which seemed to be the most important factor influencing the ease with which a nit can be removed. The three force parameters measured also showed significant correlation when compared among each other (correlation coefficient 0.252 and $P = 0.015$ for $F_{\text{peak}}$-$F_{\text{av}}$, correlation coefficient 0.352 and $P = 0.001$ for $F_{\text{peak}}$-$F_{\text{max}}$, correlation coefficient 0.725 and $P < 0.001$ for $F_{\text{av}}$-$F_{\text{max}}$).

**Discussion**

The present work was performed to develop an affordable, feasible, and reliable method to measure the parameters that determine the difficulty or ease with which nits can be removed from human hairs. We found that the force required to achieve this was largely determined by the length of the nit cylinder. $F_{\text{max}}$ also was correlated with the position of the nit with respect to the scalp end of the hair, decreasing for nits located further away from the scalp. It seemed that $F_{\text{av}}$ was the most useful measure of force because it gives an overall picture of the force development during the removal of the nit.

The device described was easy and cheap to construct with materials readily available in most laboratories. It is not possible to determine the accuracy of this method compared with other methods, because no golden standard has yet been devised for this kind of measurement.

Nits are firmly attached to the hair shaft by a solid cylinder, which does not easily break or tear when forces are exerted on it. Results show that the force needed to remove a nit mainly depends on the length of the nit cylinder. Nits with a longer cylinder have a larger contact surface with the hair shaft, resulting in more friction. The position of the nit along the hair is another variable that needs to be considered. Less force was needed to remove nits located further away from the scalp. This could be related to the fact that more distal nits might be older or had been moved previously, e.g., as a consequence of combing the hair.

Until now, little research on nits has been published. This is the first description of an objective, reproducible, and affordable procedure to measure the force needed to remove a nit from the hair. When preparing this kind of test the distance of the nit from the scalp and length of the nit cylinder should be accounted for because these factors can influence the results. From
our results, it was apparent that the average force was the most useful measure. This measuring procedure could be used to analyze the effect of treatments to remove a nit from the hair. It is our opinion that before promoting such products, their efficacy should be proven by in vitro tests before clinical studies.

Acknowledgments

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Efficacy of products to remove eggs of Pediculus humanus capitis from the human hair.

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Manuscript in preparation
Efficacy of products to remove eggs of *Pediculus humanus capitis* from the human hair.

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Efficacy of products to remove eggs of *Pediculus humanus capitis* from the human hair.

Introduction

Pediculosis capitis is a very common infestation, mainly affecting children between 3 and 12 years old. Prevalences vary from country to country but active infestation rates of almost 10% are not uncommon.\(^1\)

The egg laying process has been extensively studied in body lice. Egg laying by head lice shows great resemblance to the process in body lice. The egg and its membranes develop in the ovarioles of the female louse. They are separated from the oviduct by a plug of tissue. First the louse threads a hair between the gonopods and then some sort of glue is secreted which fills the oviduct and is spread around the hair, forming a glue tube. The plug of tissue breaks off and the egg is released into the oviduct and pushed into the glue. The glue sets and forms a solid tube or cylinder around the hair which extends into an eggshell (which is also known as a “nit”) surrounding and protecting the egg.\(^2\) The distal end of the egg consists of several domed structures and is called the operculum. This structure is not covered with glue and in vitro experiments using body lice eggs suggest that the operculum functions as a respiratory opening.\(^2\)

The presence of eggshells (with or without viable eggs) poses several problems. The first problem is that chemical treatments are often not sufficiently ovicidal. Chemical treatments should be repeated regularly to kill the newly hatched nymphs.\(^3\) \(^4\) Even if a patient is successfully treated, the empty eggshells can remain in the hair for a long time because they are firmly stuck to the hair and difficult to remove. In these circumstances, the presence of obvious nits is not only a cosmetic problem because nits are sometimes mistaken for an active diagnosis leading to unnecessary treatment.\(^5\)

Several authors have tried to unravel the composition of the eggshell. Histochemical examination of the adhesive substance using the glue glands dissected from living female lice revealed that the adhesive mainly consist of proteins.\(^2\) This finding was confirmed by Burkhart et al. who performed pyrolysis-gas chromatography and mass spectrometry on the solid nit cylinders. This study revealed a high relative abundance of components derived from phenylalanine, tyrosine, tryptophan and glutamic acid.\(^6\) \(^7\) The same authors investigated whether products such as vinegar, acetone, bleach, all purpose degreaser, petrolatum and even vodka facilitated the removal of nits in vitro. Only bleach, vodka and vinegar assisted
mildly but were not therapeutically efficacious. Mumcuoglu et al. reported that acid shampoos, 5% acetic acid, conditioners and vegetable oils are effective in detaching eggs from the hair. In most of these studies, however, the method to determine the effect of the studied products, were poorly defined and not validated. A small un-blinded clinical study demonstrated beneficial results with a nit removal system containing a formic acid 8% cream rinse and metal comb. The nit removal system was compared to a control site that was only combed with a plastic comb. However, the different type of comb alone could account for the better result in the treated site. In summary, solid in vitro and in vivo data are lacking to support the use of any of the proposed products to facilitate nit removal. Nevertheless, the formic acid cream rinse and home remedies such as vinegar are frequently cited in traditional literature reviews on the treatment of pediculosis.

The objective of the current study was to determine the efficacy of several products to remove eggshells from human by using an objective measurement procedure described in detail by Lapeere and co-workers.

Materials and methods

We recently described an objective procedure to measure the force needed to remove nits from the human hair. In the present study, we basically used the same method with some small adaptations. The force transducer, obtained from Grass Instruments (Quincy, MA), was connected to an amplifier and Lab Jack U12 USB data acquisition unit purchased from LabJack Corporation (Lakewood, CO). This device digitizes the electrical signals from the force transducer and stores them as data files on the computer, in voltage versus time. Calibration of the force transducer allows simple conversion of these data to force versus time, more precisely the force needed to displace an eggshell. From these data recordings the average force (Fav) and maximum force (Fmax) were determined with software written in Matlab (Matlab 6.1, Mathworks Inc. 2001). (Fig. 1)

A total of 605 hairs with a single nit attached at least 15 mm from the root end of the hair were collected. Approximately 14% of the eggshells contained a dead egg, whereas the rest were empty. The hairs were cut as close to the scalp as possible. The distal end of the hair was cut 20 mm behind the nit. Hairs were stored for 10 to 31 days at room temperature until they were used for experiments. The distance of the nit from the proximal end of the hair and the length of the nit cylinder were measured as previously described. (Fig. 2)

The hairs were obtained from 6 children between 7 and 11 years (average age 9). One child was recently treated with permethrin 1% shampoo, one child with a mousse containing 1%...
permethrin and 2% piperonylbutoxide, one child with malathion lotion, two children with wet combing with conditioner and one child was not recently treated.

The hairs of patient 1 and 2 were divided into 13 equal groups of approximately 25 hairs. These groups were used for the measurements in batches 1, 2 and 3.

For the 4th batch, 7 equal groups were created with the hairs of patients 3 and 4. Finally, the 5th batch consisted of five equal groups containing hairs of patients 5 and 6.

Within one batch, the hairs from two patients were divided so that all groups contained more or less the same number of hairs and that there were no differences in distance of the nit to the proximal end of the hair or length of the nit cylinder.

Because the groups within one batch were very similar, the products can be compared one to another. Batches 1, 2 and 3 can also be compared with each other because hairs from the same patients were used. They cannot be compared to batch 4 or 5 because hairs from different patients were used.

In the first batch, a short treatment with commercial nit removal products and ordinary conditioner was tested. The commercial nit removal products, available in Belgium or The Netherlands, are basically conditioners with one or more additives that are supposed to facilitate nit removal.

One group of hairs was left untreated. The second group was treated with Shampoux Balm Activ from Qualiphar (Bornem, Belgium). This product contained Hibiscus Sabdariffa as “active ingredient”. On the third group of hairs Para Balm from Medgenix (Wevelgem, Belgium) was applied, a product containing 4% acetic acid. The fourth group of hairs was treated with Neetex from Alfaco (Amersfoort, The Netherlands) which contained a non-specified quantity of citric acid and acetic acid. Finally, the fifth group of hairs was treated with ordinary conditioner (not containing any of the presumed active ingredients) purchased from Kruidvat (Renswoude, The Netherlands). The composition of these products is listed in Appendix I.

The hairs were treated according to the instructions on the package insert. The hairs were first wetted with Luke-warm running tap water before the product was applied. The product was left on for 10 minutes and rinsed before testing.

In the second batch the effect of formic acid (FA) solutions with different pH values was explored. FA and sodium formate, obtained respectively from VWR International (Leuven, Belgium) and Merck (Darmstadt, Germany) were dissolved in deionized water purchased from VWR International (Leuven, Belgium). FA solutions with a pH of respectively 2, 3, 4, 5 and 6 were prepared by changing the ratio of sodium formate to FA, and were tested on five groups of hairs. A sixth group was used to test the effect of the vehicle, which was pure
deionized water with a measured pH of 5.4. All groups were immersed in the FA solution or pure deionized water for 10 minutes and tested immediately, without rinsing. These groups were compared to the group of untreated hairs from the first batch.

In the third batch, the effect of FA in a gel vehicle was tested. A hydroxypropylmethylcellulose (HPMC) gel was prepared by dissolving 1 gram of HPMC in 100 gram of deionized water. A buffered FA gel was prepared by adding 4 grams of FA and 4 grams of sodium formate to 100 grams of the pure 1% HPMC gel. One group of hairs was treated with the blanco gel (vehicle) and a second group with the FA gel. The effect of these substances was compared to the untreated hairs (from batch one) and hairs treated with deionized water (from batch two).

In a fourth batch, we tested the effect of the consistency of the HPMC gel, but also of an application with almond oil and a long application of conditioner. A first group was left untreated and a second was treated with deionized water, as described above. The third and fourth groups were treated as previous with a basic 2% HPMC gel and a basic 3% HPMC gel. In the sixth group the effect of almond oil, obtained from Fraver (Kontich, Belgium) was explored. The oil was applied for 10 minutes and then rinsed under luke warm tap water. In the seventh group, the same oil was left on the hair during force measurement. In an eight group the ordinary conditioner was applied on the hair and left on during force measurements.

Finally the fifth batch was used to explore the effect of a long application of conditioner versus a short application. One group was left untreated; the hairs of group 2 and 4 were treated for 10 minutes with respectively the ordinary conditioner and a commercial nit removal product (Para Balm). Groups 3 and 5 were treated with the same products but the hairs were not rinsed.

Data were analyzed using SPSS software (version 12). The Kruskal-Wallis test was used to compare medians of multiple groups and the Mann-Whitney test was used to compare medians of two groups. The threshold for statistical significance was at P < 0.05.
Results

The basic characteristics of the hairs in the different batches are shown in table 1. The average distance of the nit to the proximal end of the hair varied between 37 and 66 mm, the average length of the nit cylinder was between 663 and 888 µm. Distance of the nit to the proximal end of the hair and length of the nit cylinder of all groups within each batch were not statistically significant different (SSD) from the untreated group (P values not shown). In batch one and two there were no significant differences in distance of the nit and nit cylinder length between the group treated with deionized water and all the other groups.

In the first batch we explored the effect of a short treatment with commercial nit removal products and ordinary conditioner.

The Fav needed to remove a nit from the hair in the untreated group was on average 47 ± 7 mN. Treating the hairs with a commercial nit removal product, ordinary conditioner or a soak in deionized water significantly reduced the Fav. The Fav was 18 ± 2 mN in the group treated with Neetex, which is the lowest value of all commercial nit removal products tested. (Fig 3A) In the untreated group, the Fmax was 118 ± 13 mN on average. Again this parameter was significantly reduced in all treated groups as compared to non-treatment, and was lowest in the Neetex group (60 ± mN). (Fig 4A) No statistically significant differences were observed between the various treatment regimens.

In the second batch of products based on FA solutions, the Fav was only significantly reduced in the group treated with deionized water when compared to the untreated group. Furthermore, the Fav was statistical significant higher in the groups treated with FA solutions with pH 4, 5 and 6 versus the group treated with deionized water (P < 0.05). (Fig 3A) Fmax on the other hand was SSD reduced in all treated groups versus the untreated groups. (Fig 4A)

In the third batch pure HPMC gel and a FA 4% HPMC gel was applied. Fav as well as Fmax were SSD reduced in the HPMC gel with and without FA. There was no difference between the group treated with deionized water and either of both gel. The developed forces were lowest in the group treated with pure HPMC gel with Fav equal to 25 ± 4 mN and Fmax 66 ±7 mN. (Fig 3C, Fig 4C)

A fourth batch of hairs was used to investigate the efficacy of gel composition, almond oil and a long application of ordinary conditioner left on the hair. The Fav and Fmax in the untreated group of the second batch were on average 59 ± 7 mN and 132 ± 13 mN. Both Fav and Fmax were SSD reduced in the groups treated with deionized water and un-rinsed almond
oil. Fav was significantly lower in the group treated with un-rinsed almond oil versus the rinsed almond oil (P < 0.05). Fmax was also slightly reduced in the group treated with the 3% HMPC gel. A marked and statistical significant reduction in Fav and Fmax was noted in the group treated with ordinary conditioner, left on the hair during the force measurements with Fav and Fmax being 9 ± 1 mN and 25 ± 3 mN. (Fig 3D, Fig 4D)

Finally, in the fifth batch of hairs, the effect of a short and a long treatment of both ordinary conditioner and a commercial nit removal product (Para balm) was tested. Fav and Fmax in the untreated group was 56 ± 10 mN and 140 ± 15 mN. The measured forces were significantly reduced in all treated groups versus the untreated group. Fav and Fmax were also significantly reduced in the groups where the conditioner and commercial nit removal product were left on the hair, as compared to the groups where these products were rinsed off after a 10 min application (P < 0.05). Fav and Fmax were 22 ± 2 and 69 ± 7 in the group treated with a short application of ordinary conditioner. These values were reduced to 11 ± 1 mN and 26 ± 2 mN when the ordinary conditioner was not rinsed off. A similar reduction of the forces was observed results in both groups treated with the commercial nit removal product. There were no SSD difference in measured forces between ordinary conditioner and the commercial nit removal product within the long treatment protocol and within the short treatment. (Fig 3E, Fig 4E)
Discussion

The objective and reliable method to measure the force needed to remove eggshells from human hairs that was previously described, was adapted in the present work to facilitate data handling. The Fav and Fmax measured in the three groups of untreated hairs (Fav was respectively 47 ± 7 mN, 59 ± 7 mN and 56 ± 10 mN and Fmax was respectively 118 ± 13 mN, 132 ± 13 mN and 140 ± 15 mN) were very similar to the Fav and Fmax measured with the earlier method (respectively 51 ± 3 mN and 130 ± 5 mN).

A short treatment with ordinary conditioner and commercial nit removal products significantly reduced both Fav and Fmax. However, the force needed to remove a nit was even more reduced if the product was not rinsed off the hairs before the force measurements. Furthermore, we could not demonstrate any difference between ordinary conditioners and commercial nit removal products.

Soaking hairs for 10 minutes in deionised water significantly reduced both Fav and Fmax compared to untreated hairs. Solutions of formic acid in different pH’s did not have a more pronounced effect on the force variables. On the contrary, Fav was significantly higher in the groups treated solutions with pH 4, 5 and 6 than in pure deionized water. Almond oil and HPMC gels with and without FA had some effect but this was less than the effect of the conditioners.

Recently, the tribologic properties of hair and the effect of cosmetics have been studied. Tribology is defined as the science and technology of interacting surfaces in relative motion, and embraces the study of friction, wear and lubrication. The tribologic properties of any kind of surface can be studied, including of hair.

LaTorre et al. observed that soaking undamaged hair for 5 minutes in deionised water reduced the coefficient of friction. It was hypothesized that healthy, undamaged hair is hydrophobic and that consequently more water is present on the surface resulting in a lubrication effect after soaking. The same experiment was repeated with hair that was previously chemically damaged by colouring and permanent wave treatment. The coefficient of friction increased after the hair was soaked in water. Supposedly, damaged hair is more hydrophilic and absorbs water after soaking which softens the hair and increases the area of contact with the tip of the tribologic measuring device leading to higher friction.

The lubrication effect of deionised water could explain why less force is needed to remove a nit after a soak in deionised water. Dissolving FA in deionised water did not contribute to the effect of pure deionised water. On the contrary, FA might even damage the hair leading to higher friction and an increase in force needed to remove the eggshells. An acid pH is
probably less harmful than a basic pH because the measured forces were slightly lower in the groups treated with FA solutions with lower pH.

Treating hairs with conditioner or a commercial nit removal products, according to the instructions (left on for 10 minutes and rinsed off), resulted in a reduction of measured forces, comparable to the effect of deionised water. Leaving the product on the hair, while performing the measurements, resulted in an ever more pronounced reduction. No difference was found between several commercial nit removal products and ordinary conditioner.

The key ingredients of any conditioner are cationic surfactant, fatty alcohols, water. Some products also contain silicones such as dimethicone or cycloheximethicone. Conditioner coats the hair by Van der Waals attraction making it moist and soft. Dry hair becomes easier to comb. It has been shown that a treatment with conditioner reduces the coefficient of friction of undamaged and damaged hair. This is probably why conditioners facilitate nit removal. Probably a thin film of conditioner is present on the hair during the force measurements if the conditioner is applied for 10 min and then rinsed. If the product is left on, it is possible that a thicker layer of conditioner is present on the hair resulting in more lubrication and less friction between the hair and nit.

Oils, such as almond oil, only slightly decrease the forces needed to remove nits. Furthermore, oils are difficult to remove from the hair. In the first batch, Fav and Fmax were significantly lower in the hairs treated with a 1% HPMC gel, compared to untreated hairs. In the second batch however, there was no statistical significant differences between the untreated hairs and the hairs treated with respectively a 2% and 3% HPMC gel. Even though there was no difference between the 2% and 3% HPMC gel, it might be possible that a gel with lower viscosity (and more water content) caused a slightly better lubrication effect. The fact that damaged and undamaged hairs react different to water could also explain the observed difference. The hairs in batch 4 and 5 were collected from different patients than the hairs in batch 1, 2 and 3.

Based on these in vitro observations it is very likely that an application of conditioner, left on the hair during the combing procedure, facilitates the removal of nits. The commercial nit removal products tested in the current study do not seem to have an additional effect. The addition of “active ingredients” such as formic acid or acetic acid is not beneficial and might even hamper the removal procedure.

It is not quite clear if the different structure of Caucasian, African or Asian hair has an influence on the force needed to remove nits or if this affects the efficacy of nit removal products. Furthermore, more research is needed to investigate the effect of pediculicides, products used to kill lice, on nit removal. These products might damage the nit, facilitating nit removal but might also damage the hair making it more difficult to remove nits. The effect of different ingredients in a conditioner also needs to be explored.
In the research described above, the efficacy of several products was determined by applying each product to individual hairs. The force to remove a nit was measured using a device which consisted of a metal cylinder attached to a force transducer. There are however some differences between this in vitro setting and clinical practice. Products are usually applied to the whole scalp and not to individual hairs, probably putting a different amount of product on each hair. Furthermore in daily practice a nit comb is used to remove nits, pulling at several nits at a time. It is not known if the in vitro research is representative for the in vivo setting.

This research suggests that the continuous application of an ordinary conditioner significantly enhances nit removal. Furthermore, it is a user friendly and non-toxic product, already commercial available. Clinical trials however are also needed to assess the effectiveness of the tested products in vivo.
<table>
<thead>
<tr>
<th>Applied products</th>
<th>Distance of the eggshell from the proximal end of the hair (mean ± SEM) mm</th>
<th>Length of the nit cylinder (mean ± SEM) µm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batch 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated (n= 24)</td>
<td>51 ± 5</td>
<td>824 ± 59</td>
</tr>
<tr>
<td>Shampoux Balm active (n= 23)</td>
<td>49 ± 6</td>
<td>761 ± 76</td>
</tr>
<tr>
<td>Para balm (n= 24)</td>
<td>57 ± 7</td>
<td>888 ± 64</td>
</tr>
<tr>
<td>Neetex (n= 24)</td>
<td>57 ± 6</td>
<td>812 ± 67</td>
</tr>
<tr>
<td>Ordinary conditioner (n= 24)</td>
<td>66 ± 7</td>
<td>728 ± 65</td>
</tr>
<tr>
<td><strong>Batch 2</strong></td>
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<td></td>
</tr>
<tr>
<td>Deionized water (n= 24)</td>
<td>61 ± 6</td>
<td>828 ± 86</td>
</tr>
<tr>
<td>FA pH 2 (n= 24)</td>
<td>51 ± 8</td>
<td>757 ± 55</td>
</tr>
<tr>
<td>FA pH 3 (n= 22)</td>
<td>50 ± 8</td>
<td>905 ± 89</td>
</tr>
<tr>
<td>FA pH 4 (n= 24)</td>
<td>53 ± 6</td>
<td>794 ± 82</td>
</tr>
<tr>
<td>FA pH 5 (n= 24)</td>
<td>61 ± 7</td>
<td>762 ± 59</td>
</tr>
<tr>
<td>FA pH 6 (n= 24)</td>
<td>63 ± 7</td>
<td>826 ± 70</td>
</tr>
<tr>
<td><strong>Batch 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPMC gel (n= 24)</td>
<td>52 ± 7</td>
<td>713 ± 48</td>
</tr>
<tr>
<td>FA 4% in HPMC gel (n= 23)</td>
<td>51 ± 7</td>
<td>891 ± 86</td>
</tr>
<tr>
<td><strong>Batch 4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated (n= 25)</td>
<td>55 ± 8</td>
<td>787 ± 57</td>
</tr>
<tr>
<td>Deionized water (n= 25)</td>
<td>52 ± 7</td>
<td>763 ± 56</td>
</tr>
<tr>
<td>HPMC 1% gel (n= 25)</td>
<td>54 ± 8</td>
<td>816 ± 74</td>
</tr>
<tr>
<td>HPMC 3% gel (n= 25)</td>
<td>55 ± 7</td>
<td>728 ± 51</td>
</tr>
<tr>
<td>Ordinary conditioner, non rinsed (n= 25)</td>
<td>59 ± 9</td>
<td>802 ± 51</td>
</tr>
<tr>
<td>Almond oil, rinsed (n= 25)</td>
<td>45 ± 5</td>
<td>832 ± 65</td>
</tr>
<tr>
<td>Almond oil, non rinsed (n= 25)</td>
<td>66 ± 8</td>
<td>663 ± 49</td>
</tr>
<tr>
<td><strong>Batch 5</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated (n= 25)</td>
<td>41 ± 5</td>
<td>848 ± 71</td>
</tr>
<tr>
<td>Ordinary conditioner, rinsed (n= 25)</td>
<td>39 ± 5</td>
<td>861 ± 42</td>
</tr>
<tr>
<td>Ordinary conditioner, non rinsed(n= 25)</td>
<td>43 ± 6</td>
<td>837 ± 49</td>
</tr>
<tr>
<td>Commercial product, rinsed (n= 25)</td>
<td>35 ± 4</td>
<td>811 ± 39</td>
</tr>
<tr>
<td>Commercial product, non rinsed (n= 29)</td>
<td>37 ± 5</td>
<td>819 ± 46</td>
</tr>
</tbody>
</table>
Figure 1: Plots of force development in function of time. A) Measurements in an untreated hair, B) Measurements in a hair treated for 10 min with ordinary conditioner, C) Measurements in a hair treated with ordinary conditioner without rinsing.
Figure 2: Basic characteristics of an eggshell attached to a human hair.
Fig. 3: Box plots of Fav in the different treatment groups. A) Different commercial nit removal products and ordinary conditioner, short application time. B) HPMC gel with and without FA. C) Solutions of FA with different pH. D) Almond oil long and short application time, pure HPMC gel in different consistency, ordinary conditioner long application time. E) Ordinary conditioner and commercial nit removal product in long and short application time.

* SSD from untreated with $P < 0.05$. ** SSD from untreated with $P < 0.001$
Fig. 4: Box plots of $F_{\text{max}}$ in the different treatment groups. A) Different commercial nit removal products and ordinary conditioner, short application time. B) HPMC gel with and without FA. C) Solutions of FA with different pH. D) Almond oil long and short application time, pure HPMC gel in different consistency, ordinary conditioner long application time. E) Ordinary conditioner and commercial nit removal product in long and short application time.

* SSD from untreated with $P < 0.05$. ** SSD from untreated with $P < 0.001$
Appendix I

Composition of commercial nit removal products and ordinary conditioner.

Kruidvat Balsem
Aqua, Cetearyl Alcohol, Parfum, Glyceryl Stearate, Cetrimonium Chloride, Panthenol, Parafinn, Methylparaben, 2-Bromo-2-Nitropropane-1, 3-diol, Trithylene Glycol, Propylene Glycol, Benzyl Alcohol, Methylchloroisothiazolinone, Methylisothiazolinone, Magnesium Nitrate, Magnesium Chlorite, Niacinamide, Lactic Acis, Helantius Annuus.

Para Balm
Aqua, Quaternium 18, Acetic Acid, Cetyl Alcohol, Cyclomethicone, Sodium Acetate, Parfum, Methylparaben.

Neetex
Aqua, Cetearyl Alcohol, Paraffinum Liquidum, Ceteareth-20, Citric Acid, Acetic Acid, Cetrimonium Chloride, Isopropyl Alcohol, Phenoxyethanol, Methylparaben, Butylparaben, Ethylparaben, Propylparaben, Parfum.

Shampoux Balm Activ
Aqua, Alcohol denat, Quaternium-18, Stearamine oxide, Ceteareth-25, Parfum, Polyquaternium-37, Propylene glycol dicaprylate, Dicaprate, PPG-1 trideceth-26, Hibiscus Sabadariffa flower extract.
References


Paper 5:
Knowledge and management of scabies in General Practitioners and dermatologists in Ghent, Belgium

Hilde Lapeere, Lieve Brochez, Jozef De Weert, Inge Pasteels, Jan De Maeseneer, Jean-Marie Naeyaert.

Knowledge and management of scabies in general practitioners and dermatologists

Scabies is an infectious skin disease with an increasing incidence during the past decade. A survey was conducted among general practitioners (GPs) and dermatologists in the region of Ghent, Belgium, to explore their knowledge on scabies. Information on the treatment advice given and the frequency of reporting scabies to the Health Inspection was also collected. The scores on the knowledge test were of an acceptable level in both GPs and dermatologists (median score 59% and 79%, respectively). We found that profession (dermatologist versus GP), the number of years of experience and the estimated number of scabies patients per year had a significant effect on this score. Permethrin cream, currently regarded as the standard treatment, is prescribed as the only treatment for scabies by half of the GPs and dermatologists. Almost 50% of the GPs and dermatologists indicated they rarely or never report scabies to the Health Inspection. As a result the correct incidence of scabies in Belgium, as in many other countries, is not known.

Key words: dermatologists, general practitioners, scabies

Materials and methods

The survey was carried out with a self-constructed questionnaire in Dutch. It contained questions about demographic factors, knowledge and management of scabies (table 1). The questions were based on relevant items from the literature [5-13] and on aspects that experts on the topic indicated to be important.

The knowledge questions were categorized into 5 topics involving the biology, incubation period and transmission, diagnosis and treatment of scabies, and Norwegian scabies. The questions were of the ‘true or false’ and ‘single best response’ type. One point was given for a correct answer; no points were subtracted for wrong answers or blanks. The maximum score that could be obtained was 39 points. The questionnaire was tested in a small group of resident dermatologists at the University Hospital of Ghent. GPs and dermatologists from the region of Ghent were invited to participate in this anonymous survey during a scientific meeting in 2003. The investigator ran over the questions together with the participants.

The Mann-Whitney U test was used for analysis of the differences between GPs and dermatologists on treatment preferences and hygienic advice. Because the scores on the knowledge test were not normally distributed, a cumulative logit model was used to examine the effect of three independent variables, namely profession, number of years of experience and the estimated number of scabies patients per year, on the score obtained on the knowledge test. The cumulative logit model can handle multi category responses. The parameters found in this model give the effect of each factor separately but controlled for the other independent variables included in the model.

P values below 0.05 were regarded as statistically significant. Basic statistical analysis was performed using SPSS 11.0 [14] and the cumulative logit model was obtained in SAS release 8.2 [15].

Results

Fifty-five GPs and 82 dermatologists completed the questionnaire, resulting in a participation rate of respectively 86% and 78%. Eighty-two percent of the GPs had more than 10 years of practice in contrast to only 43% of the dermatologists. Dermatologists estimated seeing more scabies patients per year than GPs. Sixty-eight percent of the dermatologists
Table 1. English translation of the questionnaire

<table>
<thead>
<tr>
<th>Demographic questions</th>
<th>Correct answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many years of practice do you have?</td>
<td></td>
</tr>
<tr>
<td>• GP or dermatologist in training</td>
<td></td>
</tr>
<tr>
<td>• &lt; 5 years</td>
<td></td>
</tr>
<tr>
<td>• 5–10 years</td>
<td></td>
</tr>
<tr>
<td>• &gt; 10 years</td>
<td></td>
</tr>
<tr>
<td>How many patients with scabies do you estimate to see per year?</td>
<td></td>
</tr>
<tr>
<td>• 0</td>
<td></td>
</tr>
<tr>
<td>• 1-5</td>
<td></td>
</tr>
<tr>
<td>• 6-10</td>
<td></td>
</tr>
<tr>
<td>• 11-15</td>
<td></td>
</tr>
<tr>
<td>• 16-20</td>
<td></td>
</tr>
<tr>
<td>• &gt; 20</td>
<td></td>
</tr>
</tbody>
</table>

Knowledge questions

A. Biology of the itch mite

Are the following statements true or false?

• T. S. scabiei has 8 legs                                                               | T               |
• T. The development from egg to adult takes 3 to 4 days                                | F               |
• T. The female makes burrows in the stratum corneum and granulosum of the skin         | T               |
• T. Nymphs and larvae are present on the surface of the epidermis                      | T               |

Scabies also occurs in animals, e.g. dogs. The organism that causes scabies in animals (indicate single best response):

- also causes scabies in humans
- causes no skin lesions in humans
- causes skin lesions looking like insect bites in humans  
  correct

When removed from the host the scab mite can survive for up to (indicate single best response):

• 12 hours                                                                              |                 |
• 24-36 hours                                                                           |                 |
• 3-6 days                                                                              | correct         |
• 2 weeks                                                                               |                 |

B. Transmission and incubation

The incubation period for scabies is (indicate single best response):

• 1-2 weeks                                                                             |                 |
• 5-7 days                                                                              |                 |
• 2-3 months                                                                            |                 |
• 1-6 weeks                                                                             | correct         |

Are the following statements true or false?

Scabies can be transmitted by:

• sex/ual contact                                                                       | T               |
• body care of a scabies patient                                                         | T               |
• being in the same room as a scabies patient                                           | F               |
• sleeping with a scabies patient                                                       | T               |
• using clothes and linen of a scabies patient                                         | T               |
• using fork and knife of a scabies patient                                             | F               |

C. Diagnosis

Are the following statements true or false?

• Itch is a typical symptom of scabies                                                  | T               |
• Itching in scabies patients worsens in the evening and at night                       | T               |
• Some patients with scabies have no itch                                              | T               |
• Itch caused by scabies disappears 4 days after an adequate treatment.                | F               |

What type of investigation can give information relevant for diagnosing scabies?

• epiluminescence microscopy                                                             | T               |
• microscopic investigation of skin scraping                                            | T               |
• blood sample                                                                           | F               |
• skin biopsy                                                                            | T               |
### Demographic questions

<table>
<thead>
<tr>
<th>D Treatment of scabies</th>
<th>Correct answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the following options is an adequate treatment for scabies:</td>
<td></td>
</tr>
<tr>
<td>• daily bathing or sauna</td>
<td>F</td>
</tr>
<tr>
<td>• permethrin 5% cream</td>
<td>T</td>
</tr>
<tr>
<td>• ivermectin 200μg/kg</td>
<td>T</td>
</tr>
<tr>
<td>• betamethasonevalerate 0.1% in cold cream</td>
<td>F</td>
</tr>
</tbody>
</table>

Which of the following local treatments for scabies are available in Belgium (either commercially or as compounded prescription?):

- Permethrin 5% cream
- Benzylbenzoate 25% cream
- Crotamiton 10% cream
- Lindane 1% cream

Are the following statements true or false?

- Permethrin cream should always be applied on two consecutive days
- Permethrin cream can cause stinging and irritation.
- A cream based on corticoids can be applied after a scabies treatment
- Permethrin should not be applied in children under 2 years of age
- Allergic eczema is a possible side effect of benzylbenzoate cream

### Practice questions

How often do you report a scabies patient to the health inspection (indicate single best response):

- Always
- Mostly
- Sometimes
- Rarely
- Never

Which of the following treatments do you prescribe (multiple answers are permitted):

- Permethrin 5% cream commercial preparation
- Permethrin 5% cream compound prescription
- Benzylbenzoate 25% cream
- Ivermectin tablets
- Crotamiton cream
- Other:

Which of the following measures do you advise patients with scabies (multiple answers are permitted):

- Washing of clothes and linen
- Isolation of clothes and linen in a plastic bag
- Isolation of clothes and linen in freezer
- Cleaning or disinfection of bedroom and living room
- Vacuum cleaning of the house
- Ventilation of mattress
- Other:
- No hygienic measures at all

---

estimated seeing six or more scabies patients per year compared to 29% of the GPs. About 40% of the dermatologists and 55% of the GPs answered that they rarely or never reported a patient with scabies to the Health Inspection. The median score on the knowledge test of all physicians was 29/39 (74%). The lowest median score was for the item biology (36 or 50%) and the highest median score was for the item transmission and incubation (67% or 86%) (figure 1). When incorporated in the cumulative logit model, profession, number of years of experience and estimated number of patients all had a statistical significant effect on the score on the knowledge test (table 2). The odds of obtaining a
Part VII: Research papers

Paper 5

Table 2. Results of the cumulative logit model

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>P value</th>
<th>Corresponding Odds Ratio</th>
<th>1/OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profession</td>
<td>-2.5232</td>
<td>&lt; 0.001</td>
<td>0.080</td>
<td>12.5</td>
</tr>
<tr>
<td>Number of years of experience</td>
<td>-0.4115</td>
<td>0.009</td>
<td>0.663</td>
<td>1.51</td>
</tr>
<tr>
<td>Estimated number of scabies patients</td>
<td>-0.5267</td>
<td>&lt; 0.001</td>
<td>0.591</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Corresponding Odds Ratio: Odds Ratio for a higher category of the independent variable versus a lower category to have a certain score at most versus a higher score. 1/OR: Odds Ratio for a higher category of the independent variable versus a lower category to have a higher score on the knowledge test.

 Permethrin cream is prescribed by more than 90% of both dermatologists and GPs. Only 20% of those prescribing permethrin make compounded prescriptions. For about half of the dermatologists and GPs, permethrin cream is the only treatment prescribed for scabies, meaning they do not prescribe concomitant medication. Ivermectin tablets are prescribed by 24% of the dermatologists whereas none of the GPs had ever prescribed this drug (Table 3). Finally, the hygienic advice given by dermatologists and GPs was similar. All of the dermatologists and GPs advise their patients either to wash all their clothes and linens or to keep it in a plastic bag. Thirty-five percent of the GPs and 9% of the dermatologists advised mopping or disinfecting the bedroom and/or living room (P < 0.001).

Discussion

This survey reports on the knowledge and management of scabies in GPs and dermatologists in a Western European country. One comparable study on knowledge of scabies has been performed in Pakistan [16]. The total scores on knowledge about scabies were of an acceptable level in both dermatologists and GPs. The median score was lowest for the items biology and Norwegian scabies. Basic knowledge about these items is important because of the implications for treatment, transmission and prevention. Scabies is caused by S. scabiei var. hominis. The female mite makes burrows in the stratum corneum and granulosum of the skin in which the eggs are laid. The incubation period for scabies is 1 to 6 weeks, meaning that patients can already be infested before they notice any clinical sign or symptom [6]. Scab mites strongly depend on the warm and humid environment of their host. They can survive outside the host for about 36 hours [5]. The scab mite is also host specific, meaning that other variants (e.g. var. canis in dogs) do not cause scabies in humans. These animal variants can be responsible for a temporary skin eruption in humans that is, however, clinically different from scabies. Scabies in humans is mainly transmitted by bodily contact with another scabies patient and not by pets. Norwegian scabies occurs when patients are infested with thousands of mites. This type of scabies is also caused by S. scabiei var. hominis and presents clinically with thick psoriasiform crusts on hands and feet and nail dystrophy. Norwegian scabies can occur in immune compromised patients (e.g. HIV patients) or in patients with decreased itch sensation (e.g. dementia) [6].

The score on the knowledge test was influenced by profession, number of years of experience and the estimated number of scabies patients. Physicians (GPs as well as dermatologists) who see more scabies patients have more experience with the disease and

Figure 1. Box plot of total score on the knowledge test and scores per topic for GPs and dermatologists.

* : P < 0.05. ** : P < 0.001.

higher score are 12.5 times higher in dermatologists than in GPs. Similarly the odds of obtaining a higher score are 1.51 times higher per increasing category of practice experience and 1.69 times higher per increasing category of the estimated number of scabies patients.

Table 3. Treatments prescribed by GPs (n = 55) and dermatologists (n = 82)

<table>
<thead>
<tr>
<th>Name of the treatment</th>
<th>% prescribing this treatment</th>
<th>% prescribing this treatment only</th>
<th>% prescribing this treatment</th>
<th>% prescribing this treatment only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permethrin cream</td>
<td>93</td>
<td>47</td>
<td>94</td>
<td>50</td>
</tr>
<tr>
<td>Benzylbenzoate cream</td>
<td>27</td>
<td>2</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Crotamiton cream</td>
<td>6</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Ivermectin oral</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>5</td>
</tr>
</tbody>
</table>

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therefore know more about scabies than physicians who see less scabies patients. However, it is also possible that physicians with lower test scores do not recognize scabies when confronted with the disease and therefore estimated seeing fewer patients than their colleagues with higher test scores. The same explanation could account for the observation of the higher score in the knowledge test in physicians with more practice experience.

Finally dermatologists obtained a higher score than GPs. Several factors could account for this difference, eg scabies will probably be more frequently discussed in the scientific literature or meetings for dermatologists than for GPs. About 40% of the dermatologists and 55% of the GPs admit that they rarely or never report scabies patients to the Health Inspection. This proportion could be even higher in daily practice because participating physicians could have been biased to give an answer that is socially acceptable (social desirability bias) [17].

Permethrin cream is by far the most popular treatment for scabies; more than 90% of the dermatologists and GPs prescribe this treatment. Permethrin cream is currently considered as the standard treatment for scabies [8]. It should be applied at least once over the total body from the jaw line downwards. In children and bedridden patients the scalp should also be treated [6]. The commercially available product is however expensive in Belgium. Another option is a compounded prescription, which is about 50% cheaper. A compounded prescription is a product prepared by the pharmacist according to the order of the prescribing physician. In our survey only 1 in 5 physicians prescribing permethrin considered the compounded prescription. It is important that all possible contact persons are treated at the same time, even if they do not have symptoms [13]. The cost of treatment, often for several persons, is important for patients and might influence their compliance.

The efficiency of ivermectin in the treatment of scabies has recently been described in the literature [9, 13, 18-20]. In our sample of physicians it was only occasionally prescribed by dermatologists. Ivermectin is not registered in Belgium and physicians who want to prescribe this medication have to fill in special forms along with the classic prescription. Furthermore, the local pharmacist can only order ivermectin in France or Holland. This probably explains why it is primarily prescribed in secondary health care by dermatologists.

In the classic forms of scabies, the patient is infested with a low number of scab mites. Clothes and linen can contain viable parasites and should be washed at 60 °C or separated in plastic bags for 2 or 3 days. It is unlikely that mites are spread in the environment of the patient [13]. Furthermore, the mite’s chances of survival are limited once they get separated from their host [6]. Therefore it is generally accepted that it is not necessary to clean or disinfect the house, furniture, carpets, etc. [5]. In the current survey about 33% of the GPs and 9% of the dermatologists advise their patients to clean or disinfect bedrooms or living rooms. A reason for this could be that GPs are less familiar with the mite’s biology and transmission. In Norwegian scabies, which rarely occurs, patients are infested with millions of mites that are shed in the environment. Special isolation measures, cleaning and disinfection of the environment are appropriate in those cases [6].

This survey was done with a self-constructed questionnaire that was not validated before use. However it was not the intention to develop a universal instrument to test knowledge and practice of scabies but rather to explore the knowledge on the current insights in scabies and to identify a need for education programs in local GPs and dermatologists. The physicians participating in this survey were attending a scientific meeting and knew about the scabies survey. The dermatologists came from a large region in Flanders while the GPs were all from the region of Ghent. This difference could have an effect on the results. It is also possible that responders tend to give answers that put them in a positive light, even though the survey was anonymous. These factors could have influenced the results of the questionnaire. Nevertheless, these results can give some idea of the way GPs and dermatologists in Belgium manage scabies.

Acknowledgements. We would like to thank all the physicians who participated in this survey. This research was supported with a grant from Ghent University, BOF2002/DRMAN/007.

References
